MAY, 1958

JOURNAL OF THE IRON AND STEEL INSTITUTE

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VOL. 189 PART 1

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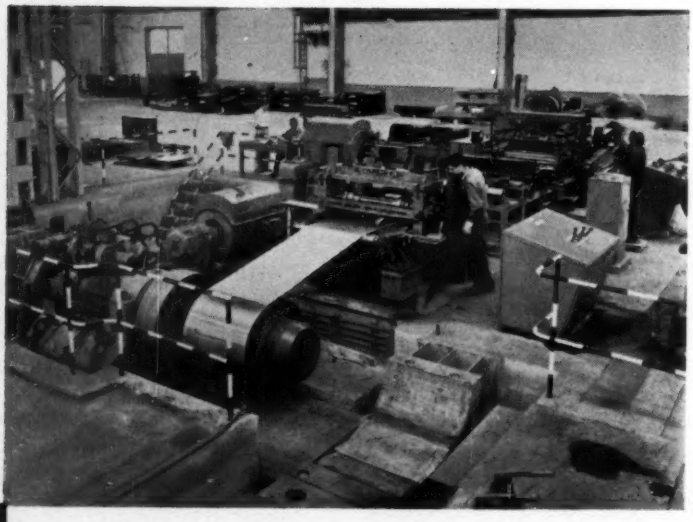
TINPLATE FLYING SHEAR LINE by DAVY-UNITED



This Flying Shear Line is at work in the steel strip and tinplate plant recently established at Piombino in Northern Italy by Spett S.A. La Magona d'Italia. Installed in conjunction with two Davy-United 48″ and 38″ Cold Mills and a Davy-United Continuous Electrolytic Cleaning Line, it is designed for an annual capacity of 30,000 tons. Coils are dealt with up to 38″ wide and these are side-trimmed and sheared on the Line to produce sheets up to 37″ maximum width. Strip thicknesses range from .006″ to .025″ and cut lengths can vary from 12″ to 52″, the operating speed being 40/300 feet per minute.

The top picture shows the combined Roller Leveller and Flying Shear Unit which is an essential part of the line.

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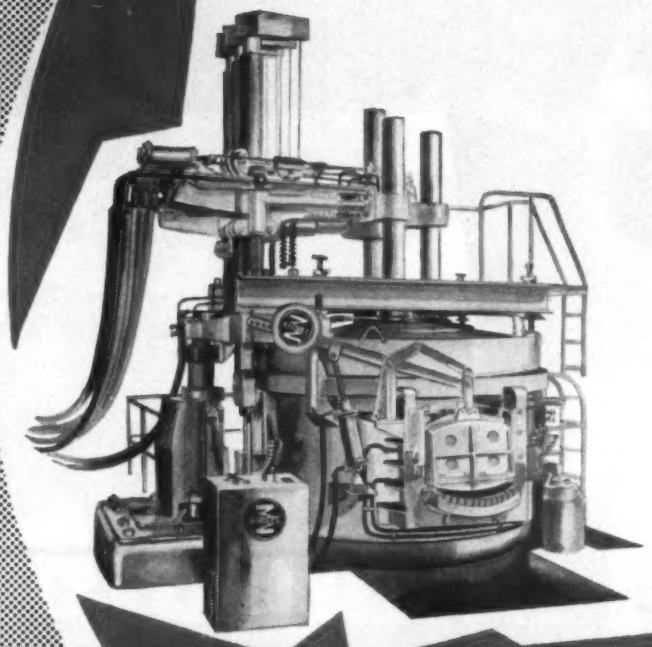
Steel Foundry Furnaces



The foundryman who is fortunate enough to be in charge of a Birlec arc melting furnace quite literally has everything under control — largely automatic control. The power input, and therefore the bath temperature, is easily adjusted within wide limits. Automatic and sensitive regulation of the arc by the Amplidyne system allows maximum power to be maintained throughout the melting cycle, promoting a high output. Birlec design features — water cooling of parts exposed to heat, and hydraulic roof removal for rapid top charging — secure the dependability and continuous high production capacity essential to competitive steel foundries.

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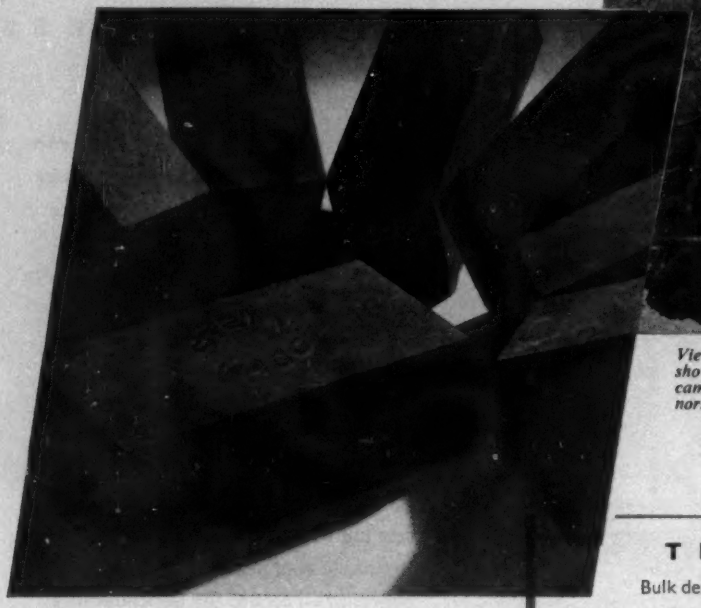

View of end wall of basic open hearth furnace showing excellent condition of Mag C after a campaign of 22 weeks. Target area in silica normally lasts only 2/3 weeks.

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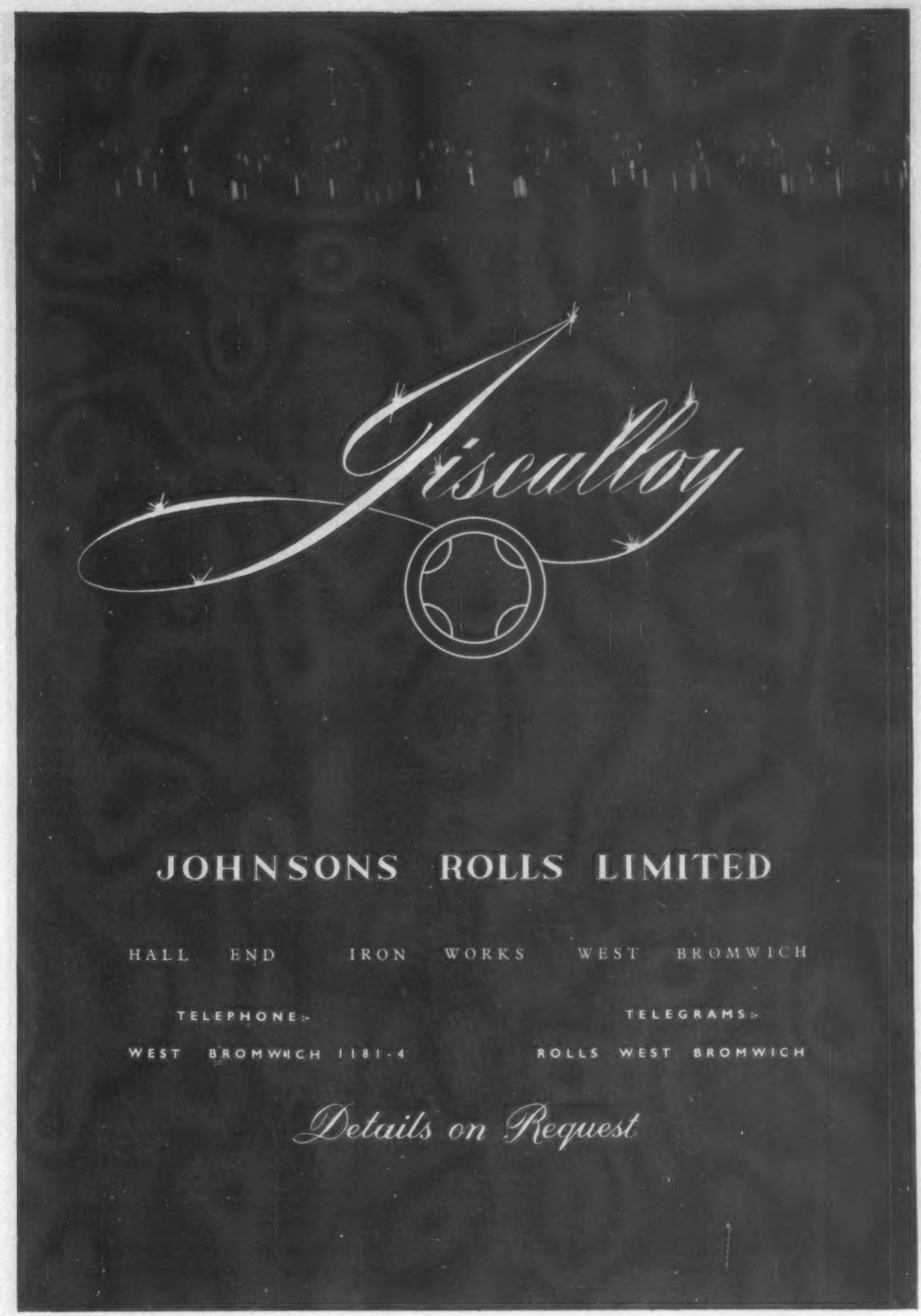
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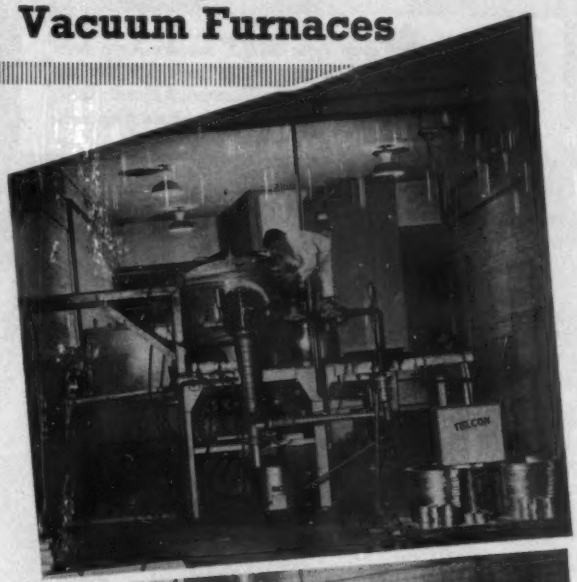

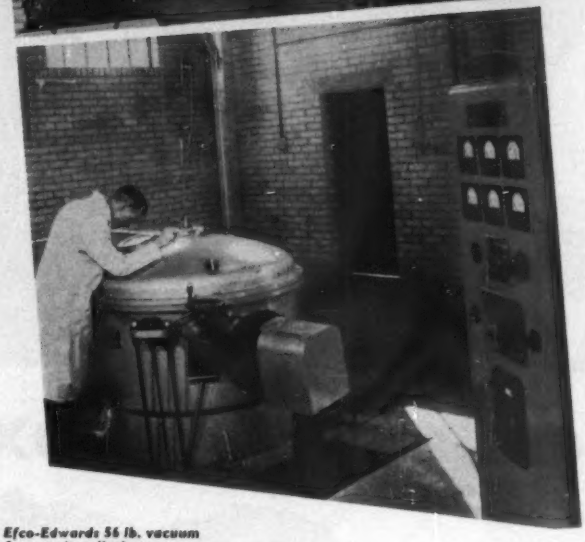

A child designed the first Supersonic flier!

The paper dart fashioned by childish fingers bears a unique similarity to the supersonic flier . . . its shape . . . its slimness . . . its simplicity, but the resemblance fades here, for under that gleaming cowl lies a complex engine designed to withstand phenomenal temperatures and stresses, and behind the engine lie the great achievements of VACUUM METALLURGY!

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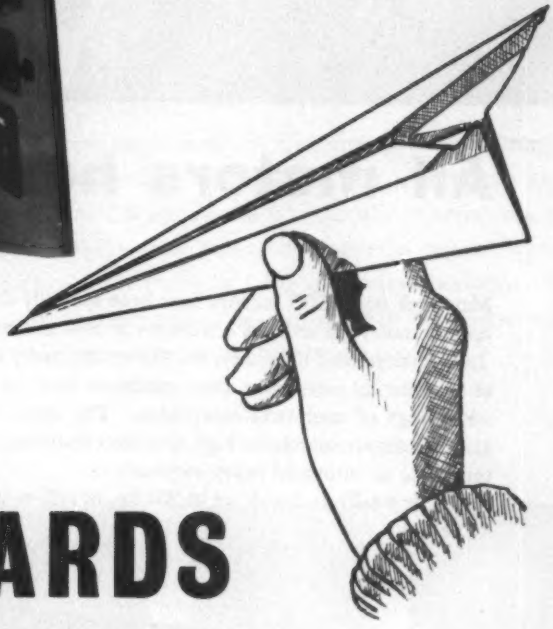
Efco-Edwards 56 lb. vacuum furnace installations

Top: Vacuum melting Telcon "Mumetal" magnetic materials.
By courtesy of The Telegraph Construction and Maintenance Co. Ltd.

Below: Vacuum melting special alloy steels.
By courtesy of G. L. Willan Ltd.



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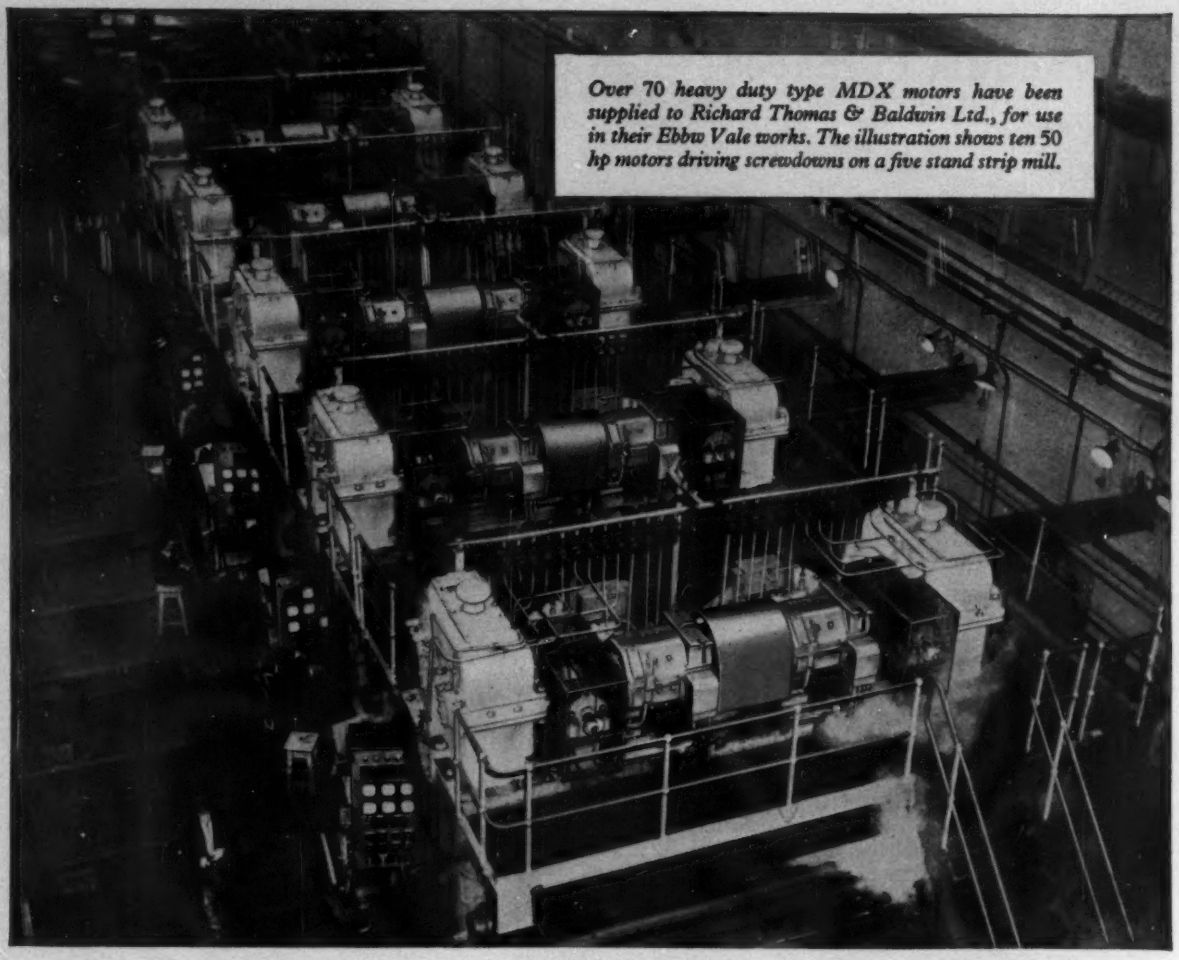

Over 70 heavy duty type MDX motors have been supplied to Richard Thomas & Baldwin Ltd., for use in their Ebbw Vale works. The illustration shows ten 50 hp motors driving screwdowns on a five stand strip mill.

All motors here are type MDX

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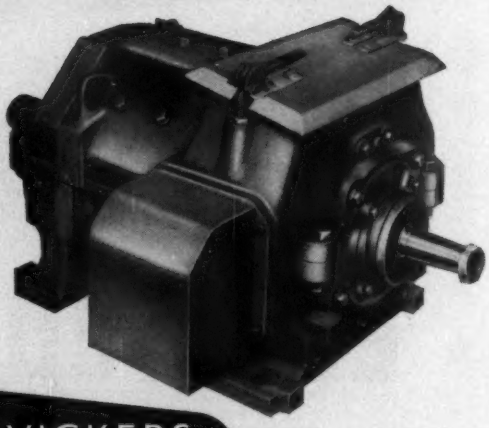

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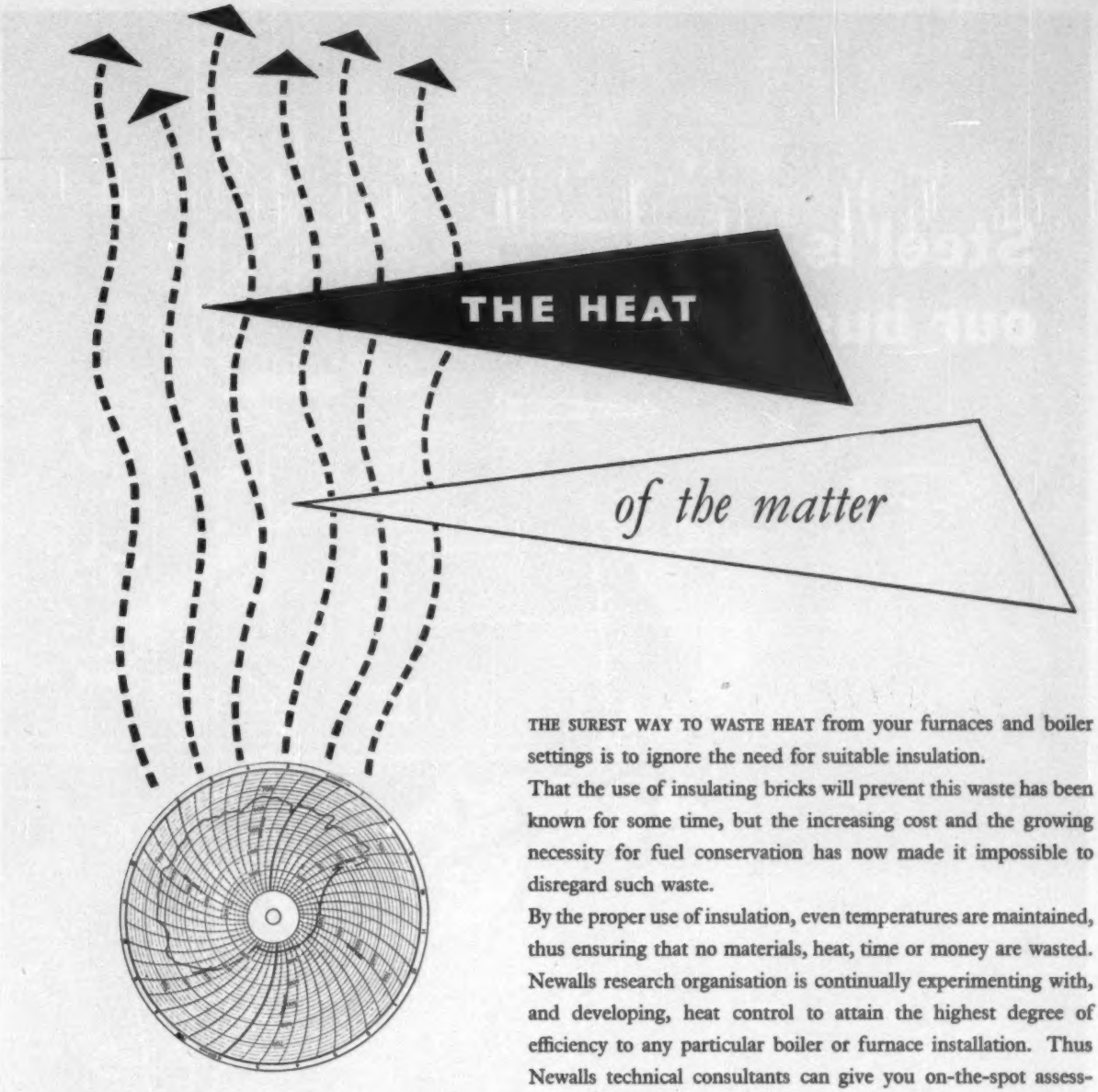

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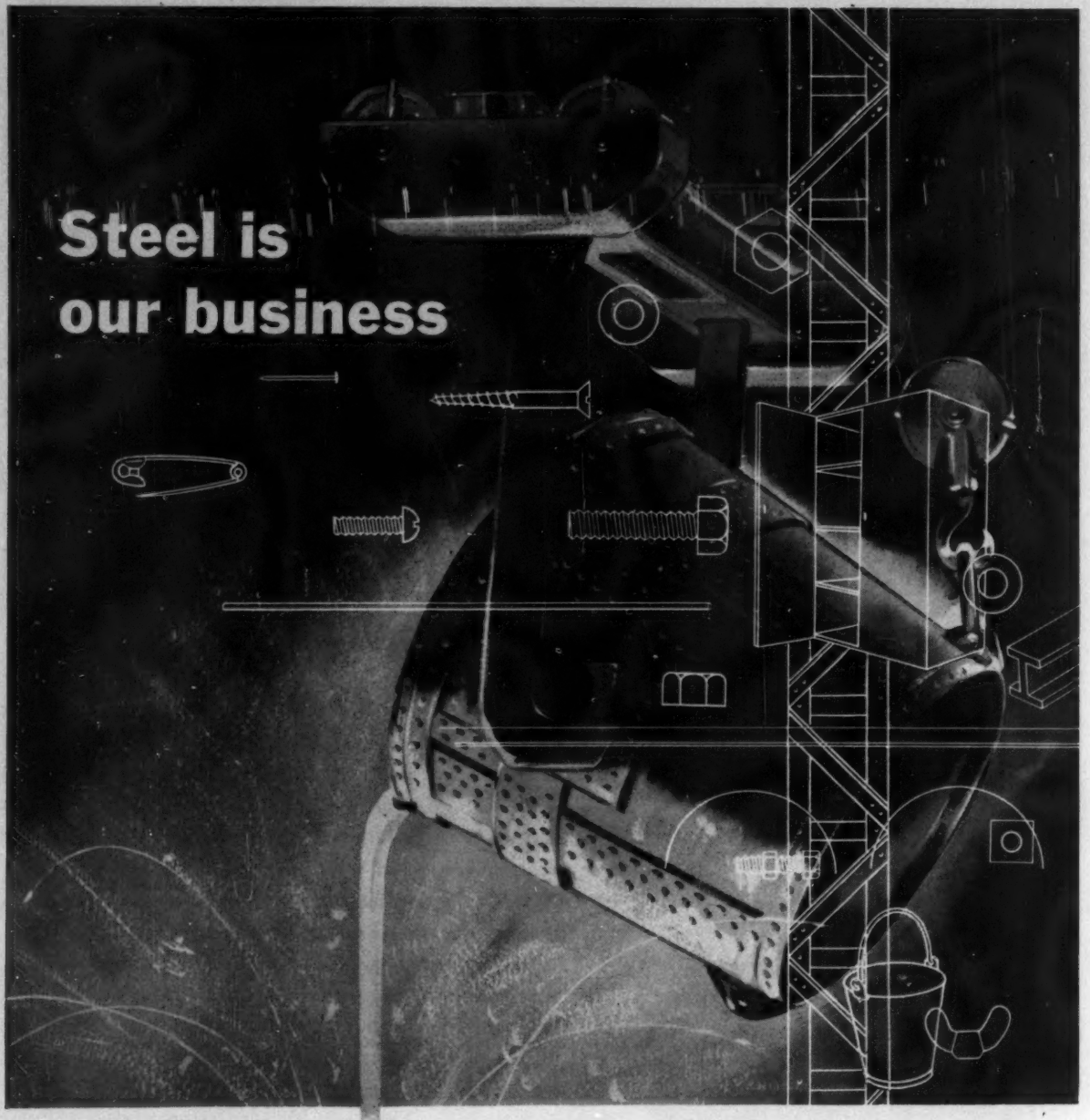

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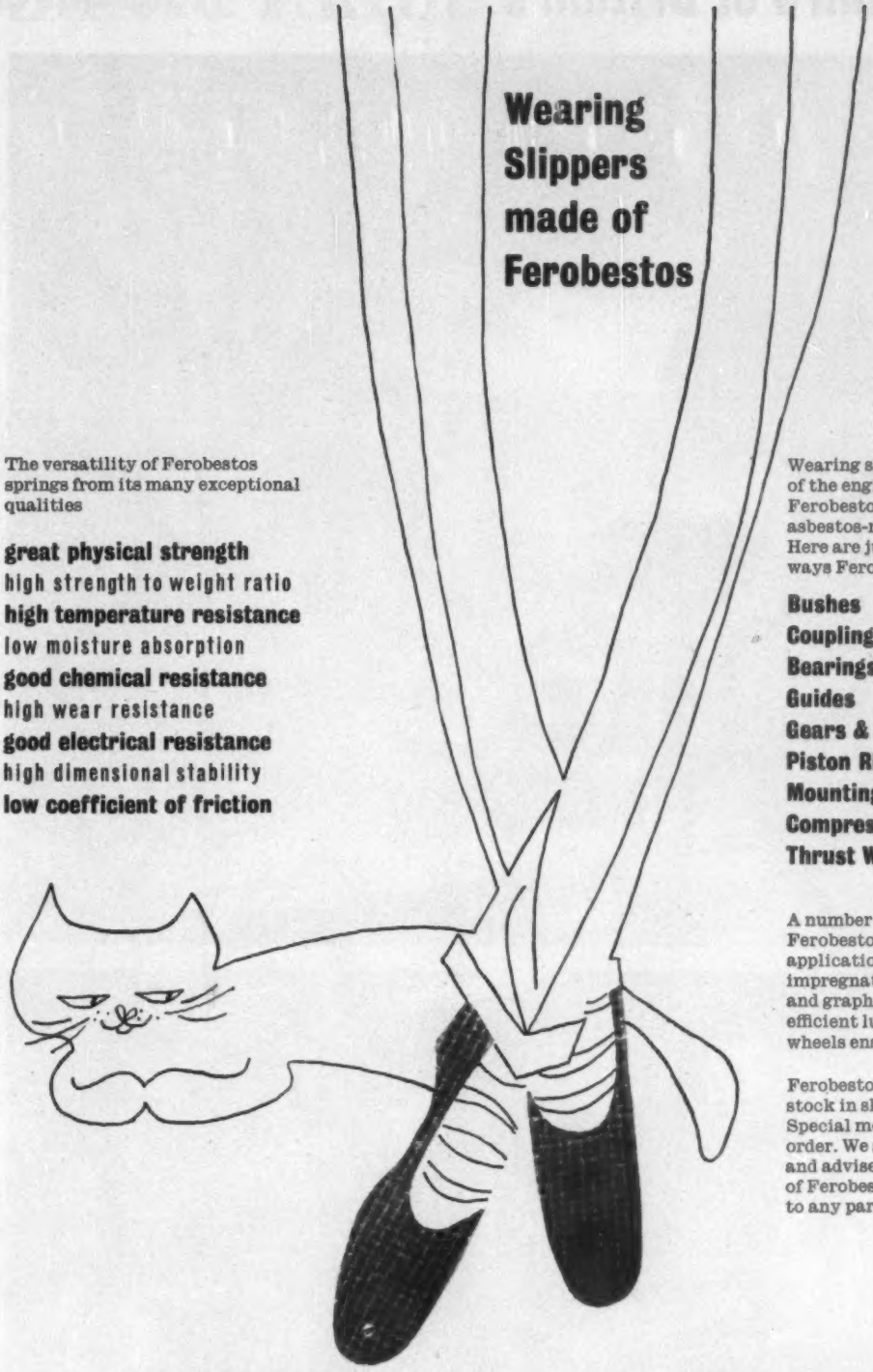
Wearing Slippers made of Ferobestos



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high strength to weight ratio
high temperature resistance
low moisture absorption
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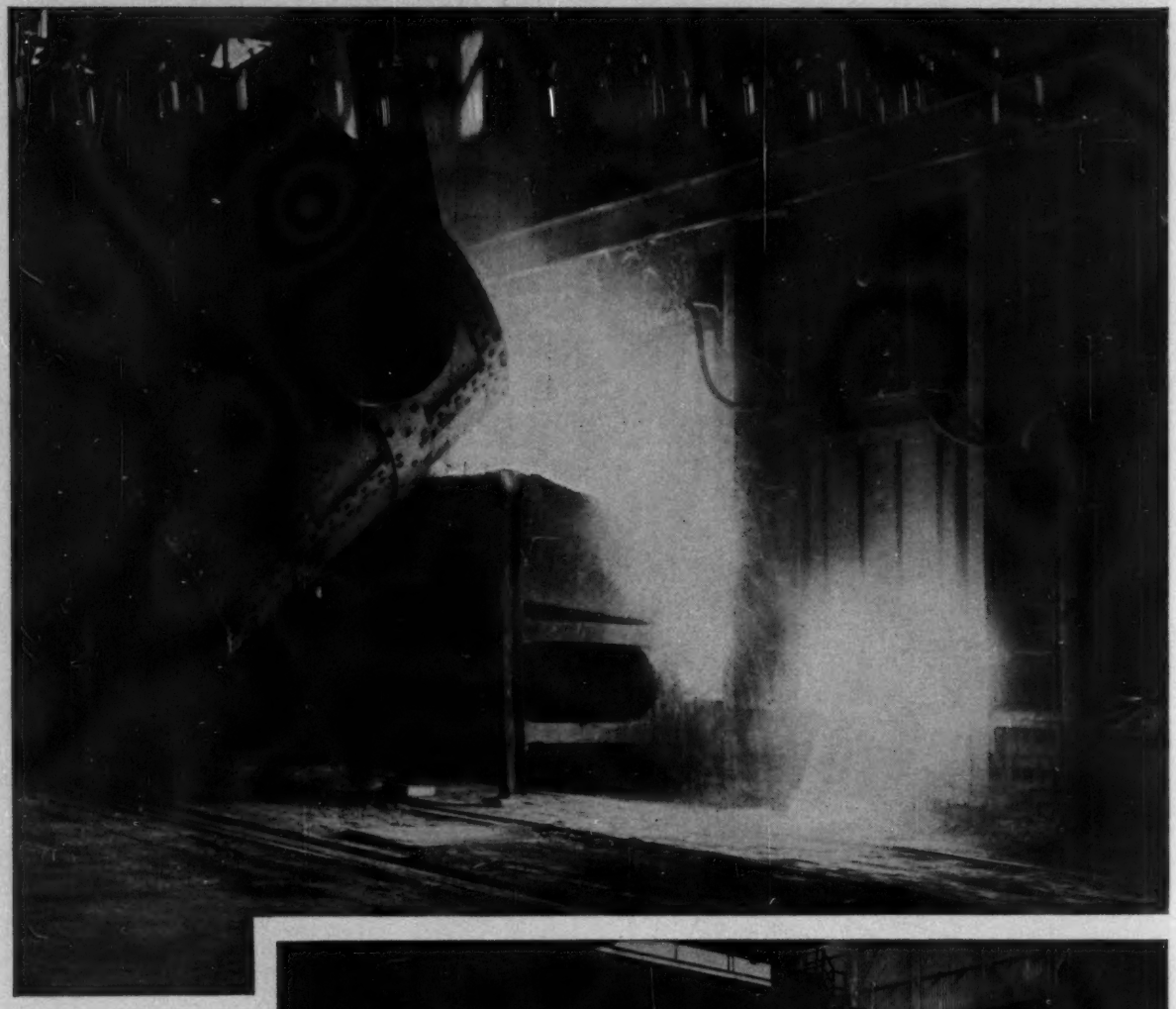
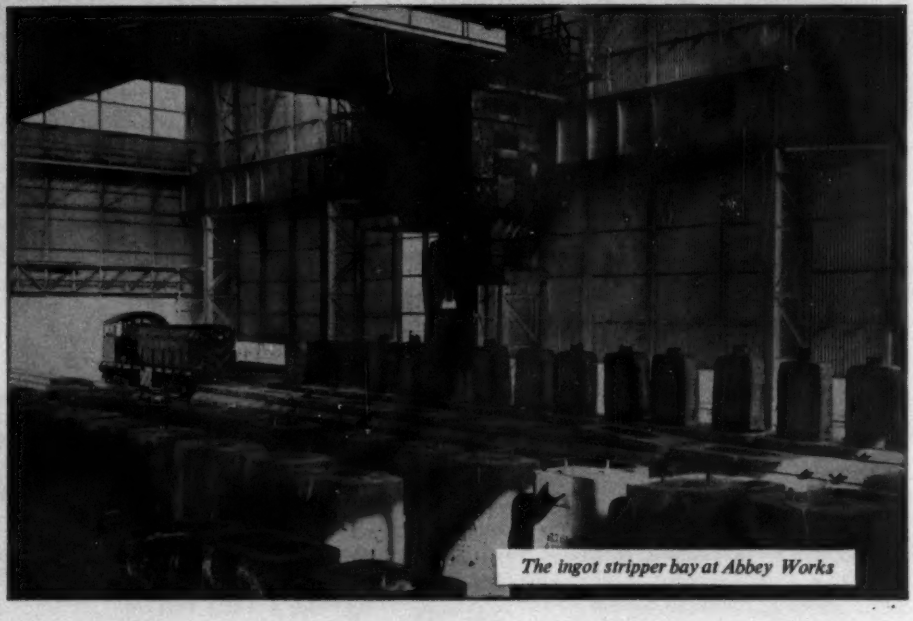


Molten iron being charged into an open hearth furnace at Abbey Works



The ingot stripper bay at Abbey Works

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The slabbing mill motor room at Abbey Works

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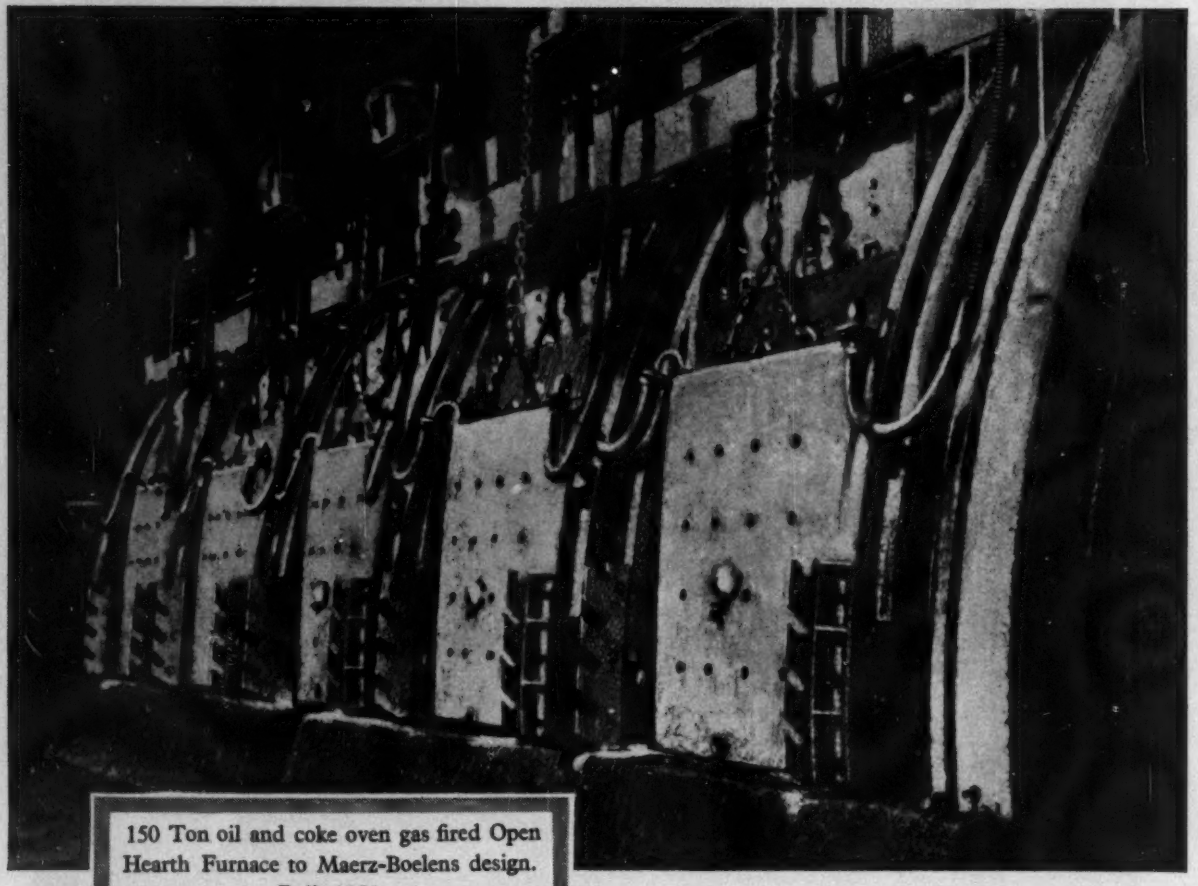

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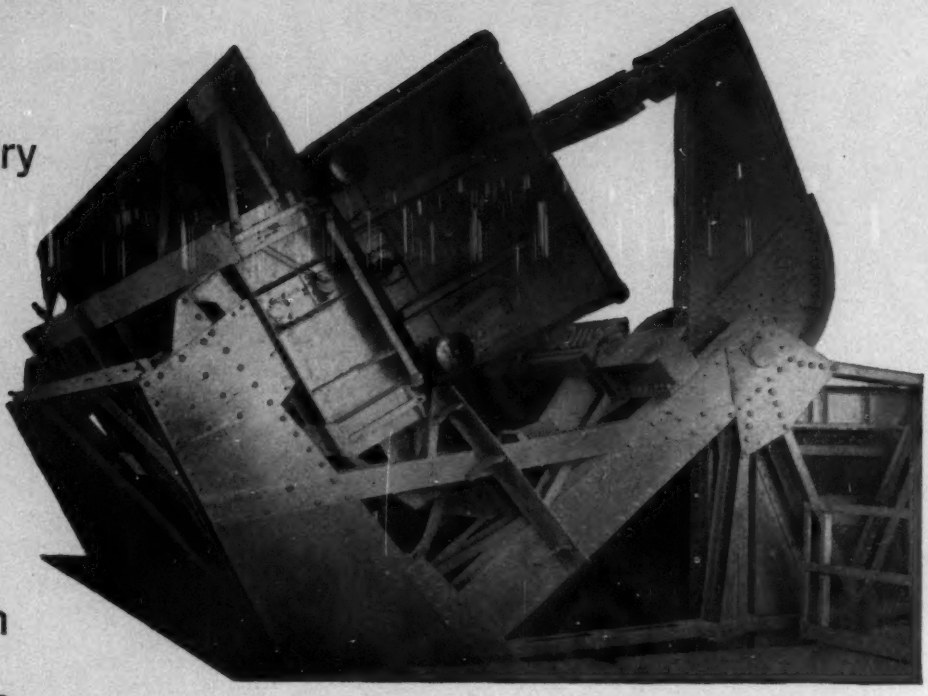

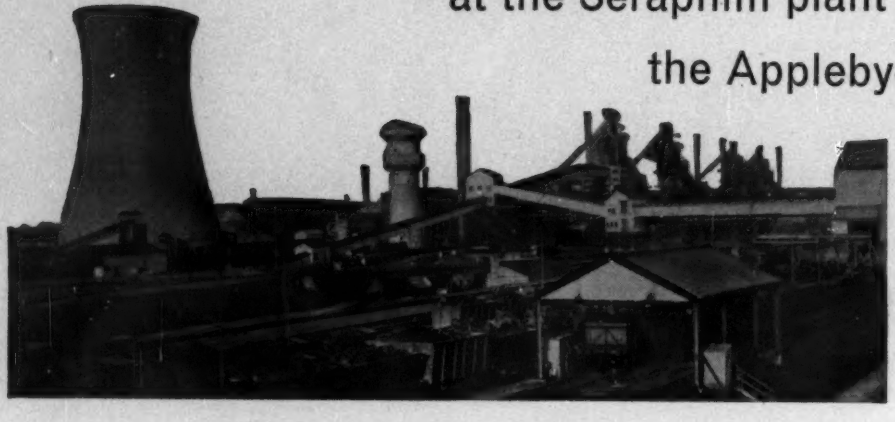

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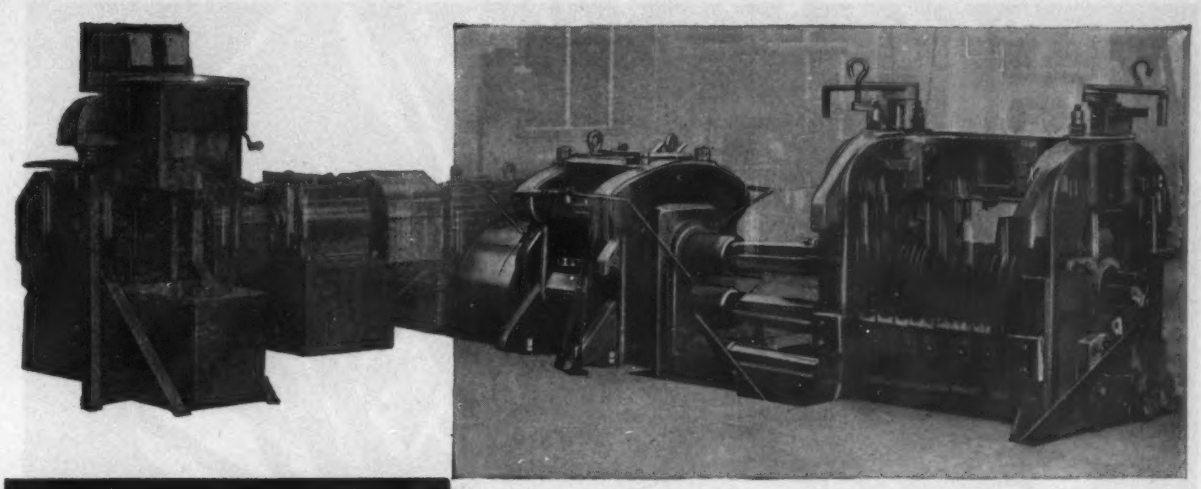

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12" Mill as supplied to Swinden Laboratories, Rotherham, and published by courtesy of The United Steel Companies Ltd.

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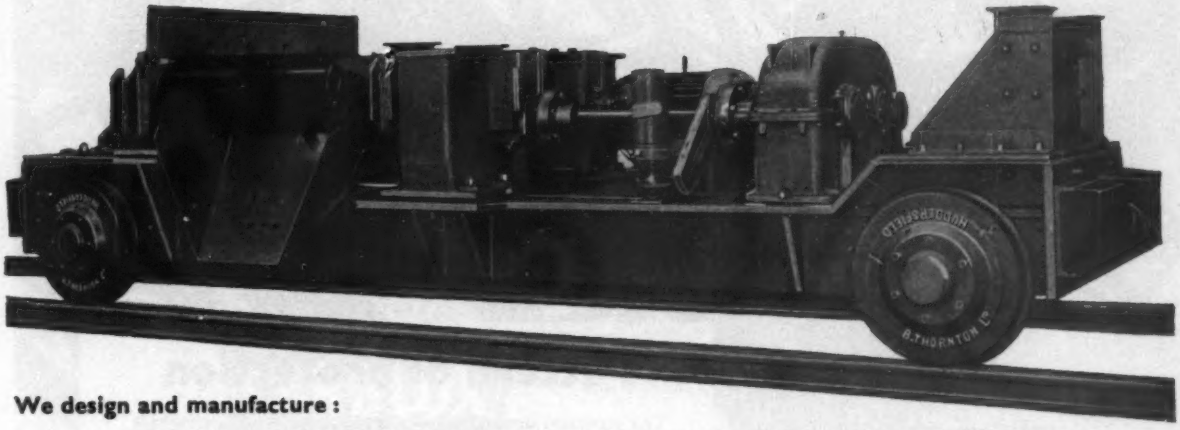

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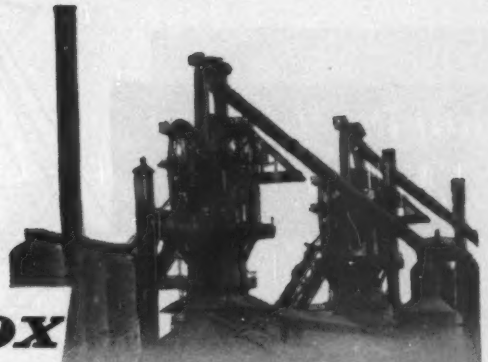

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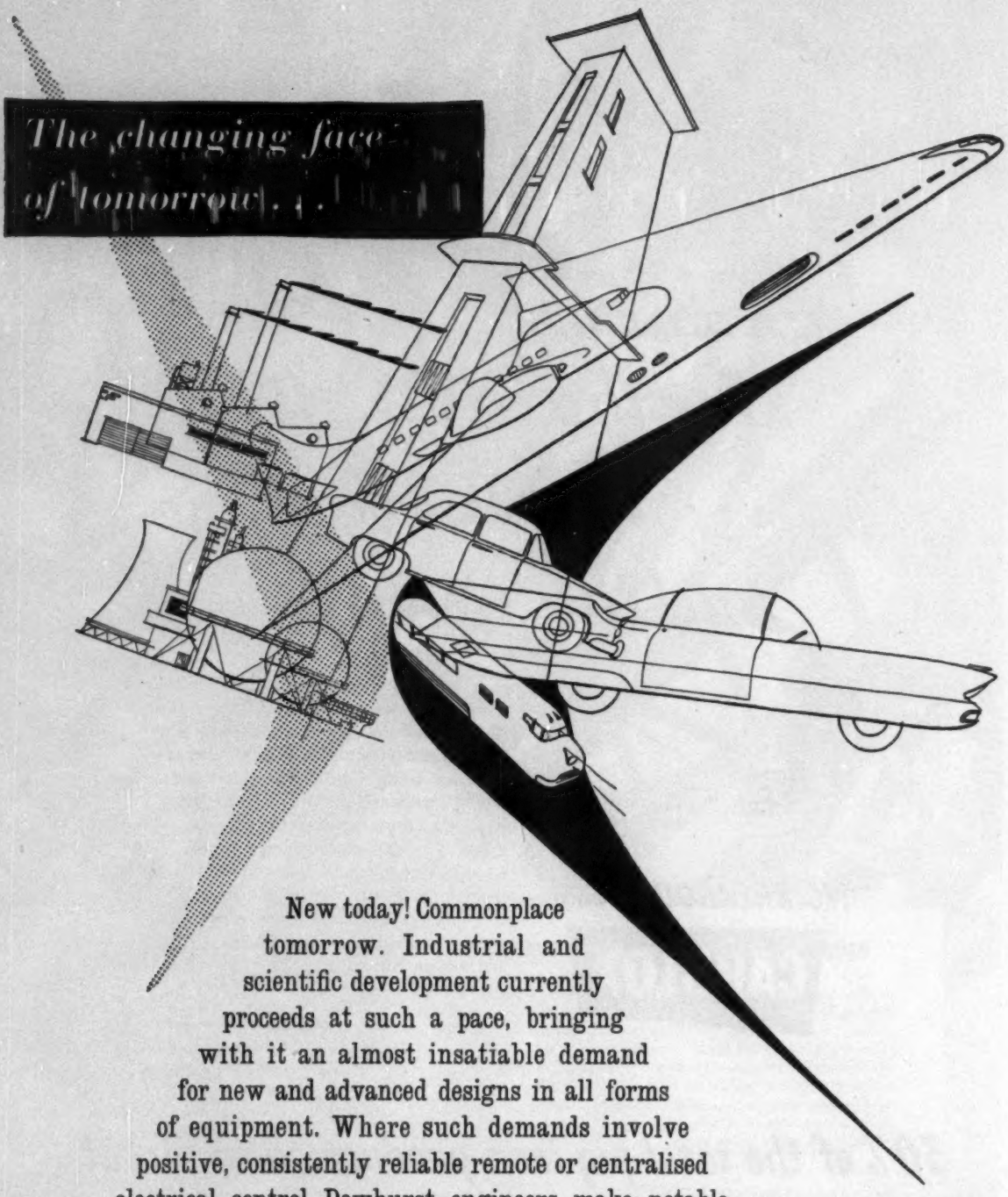

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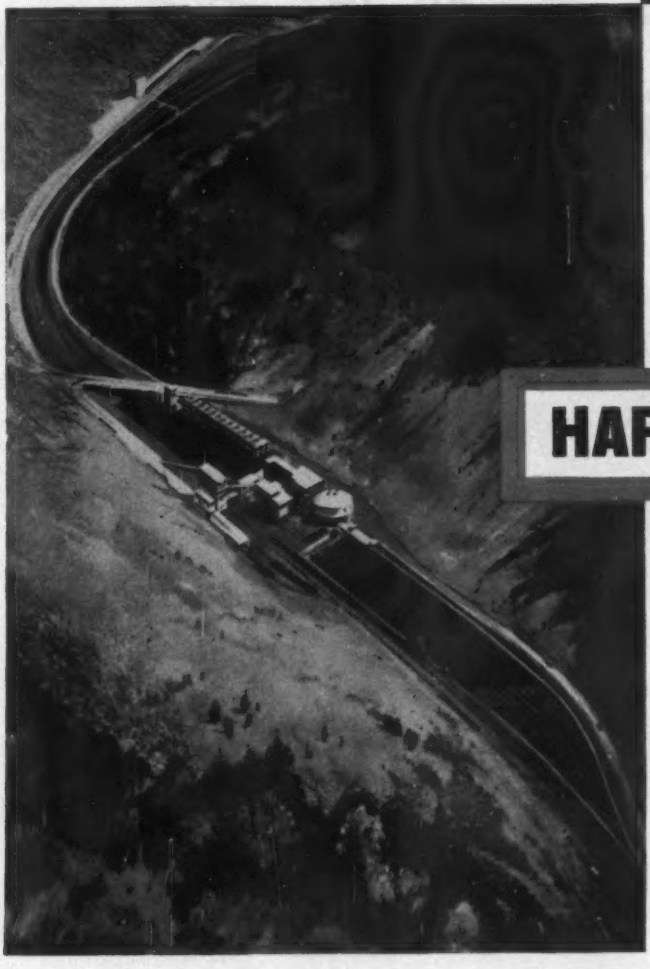

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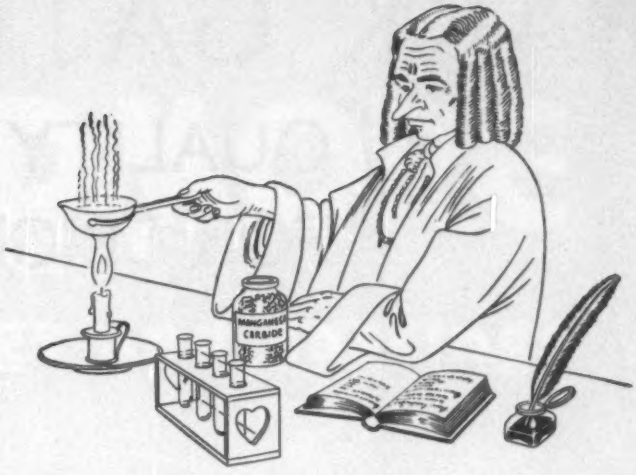

The use of spiegeleisen as adopted in 1856 by Robert Mushet made the Bessemer process a practical success by converting the oxidised ' ingot iron ' into forgeable steel.

William Siemens was the next notable figure to appear on the scene and he patented the use of ferro manganese as an addition to molten steel to counteract the adverse effect of sulphur. Robert Hadfield in 1888 made a tremendous advance when he announced the discovery of the high manganese steel now generally known as Hadfield manganese steel.

Standard ferro manganese is always relatively high in carbon and thus it has disadvantages where steels require a high manganese but a low carbon content. Electric furnaces however have made possible the production of refined grades of ferro manganese and this particular problem has been overcome.

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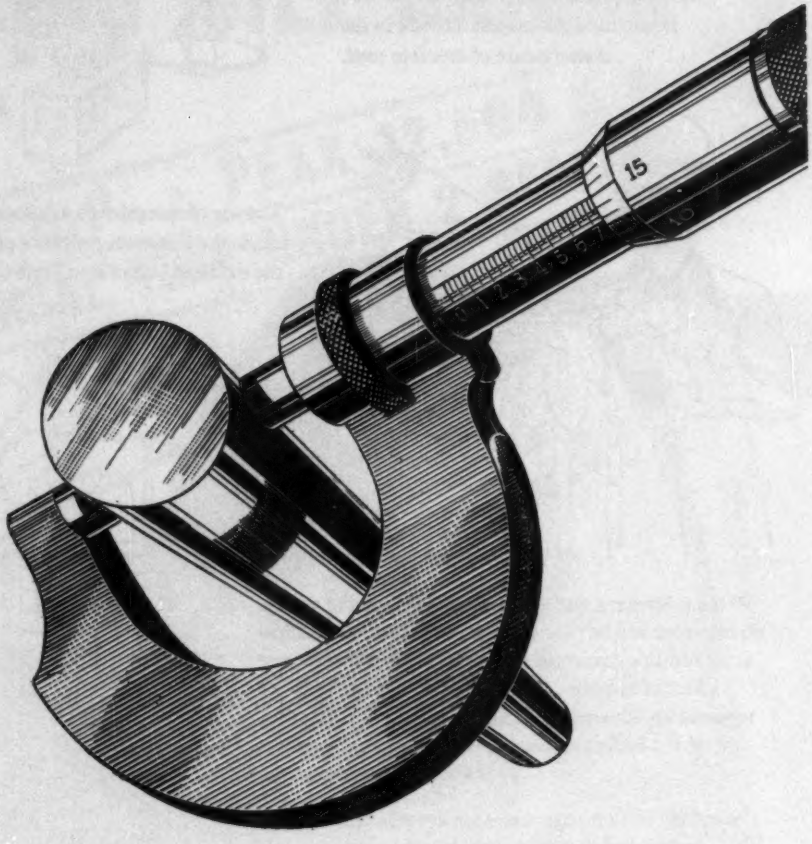

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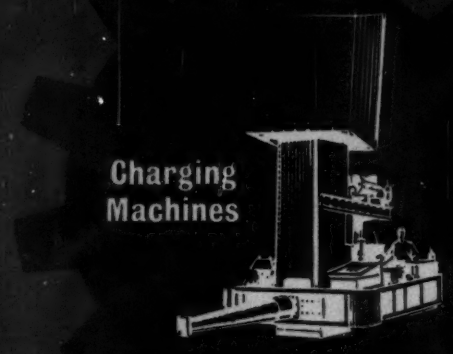

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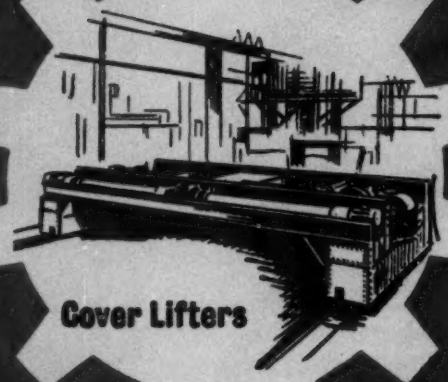

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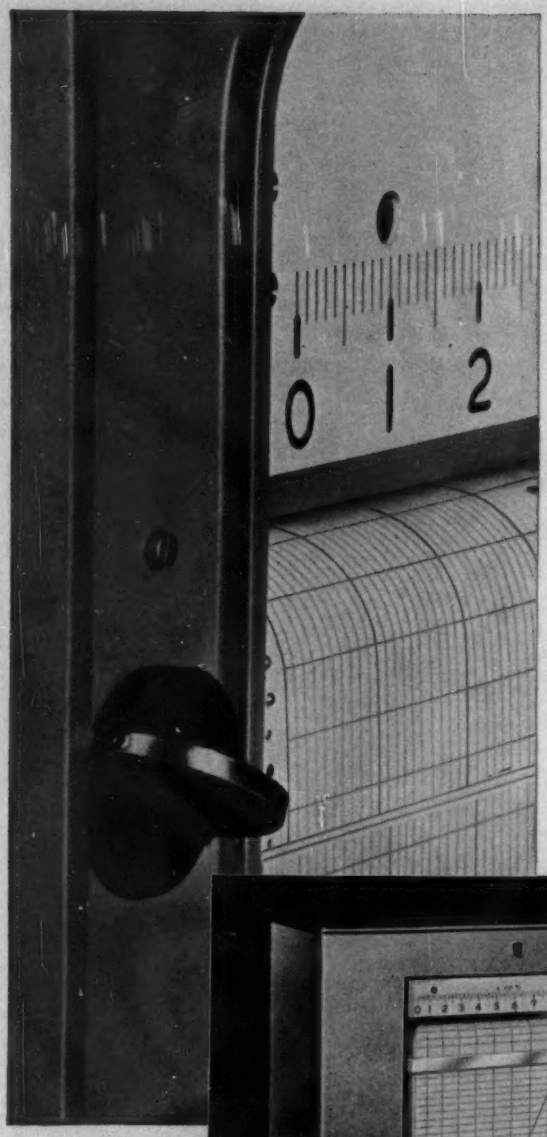

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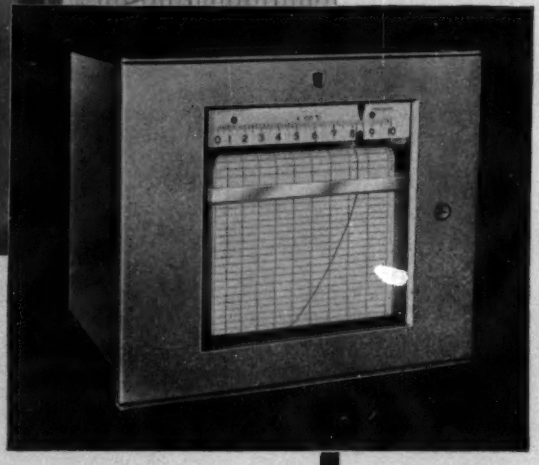

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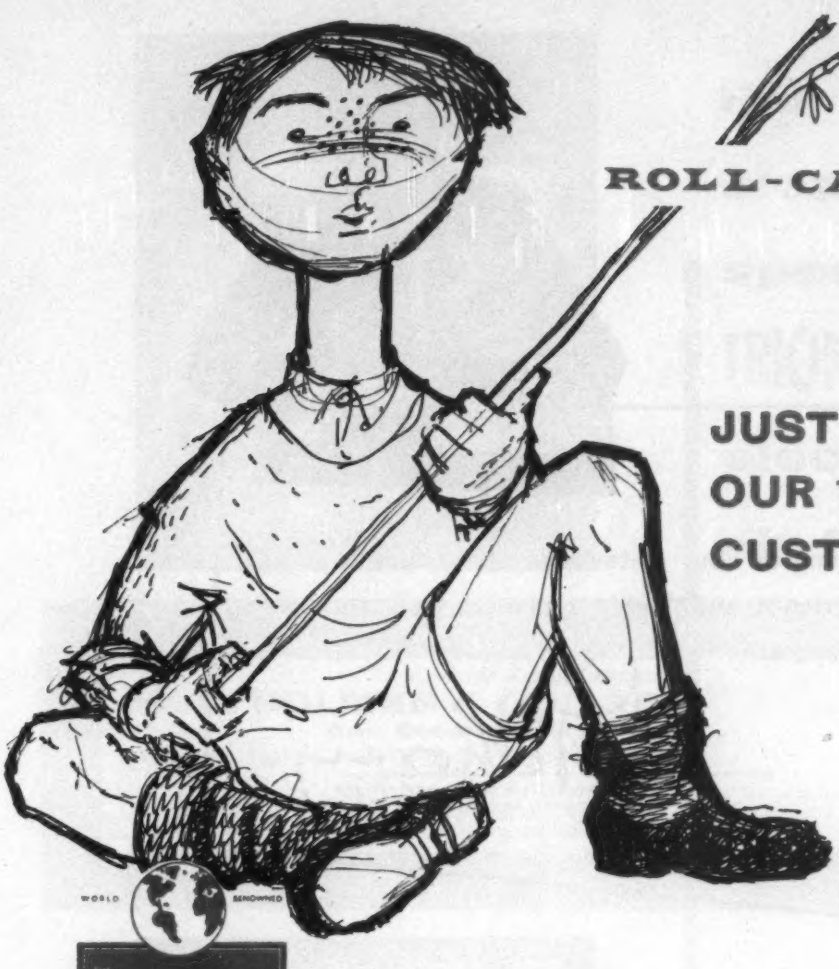

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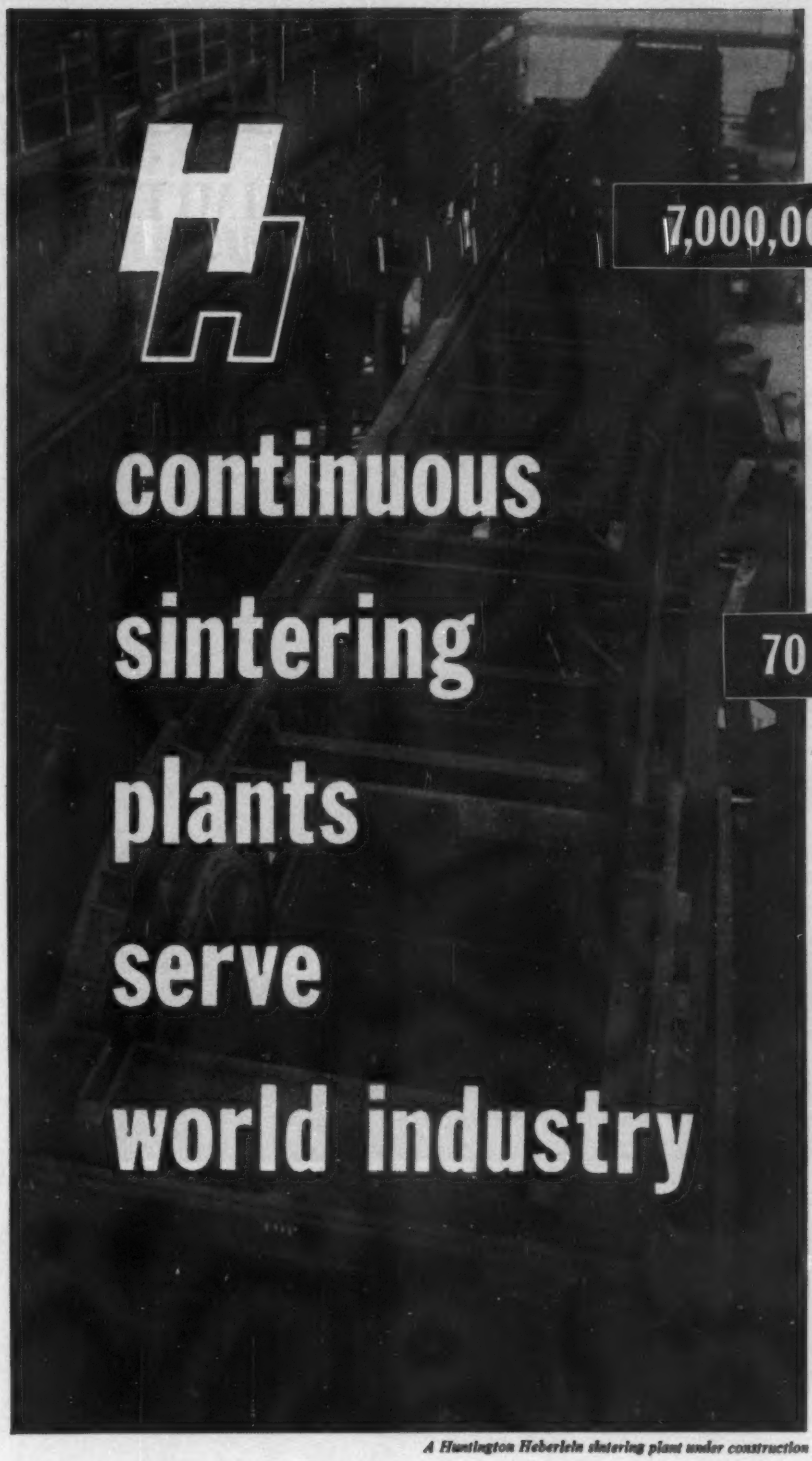

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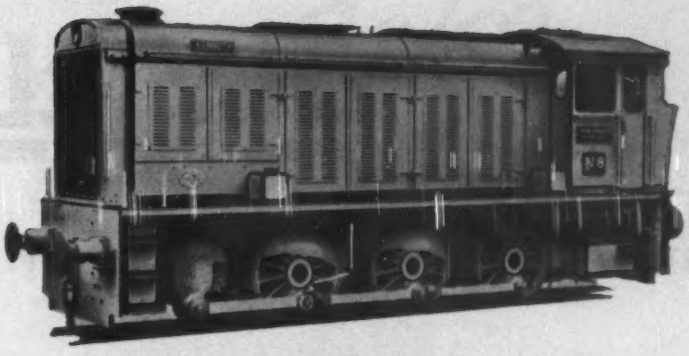

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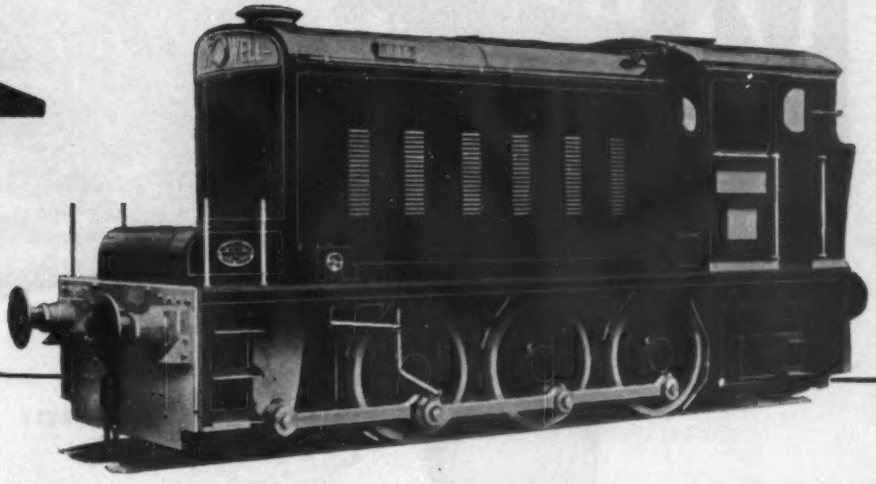

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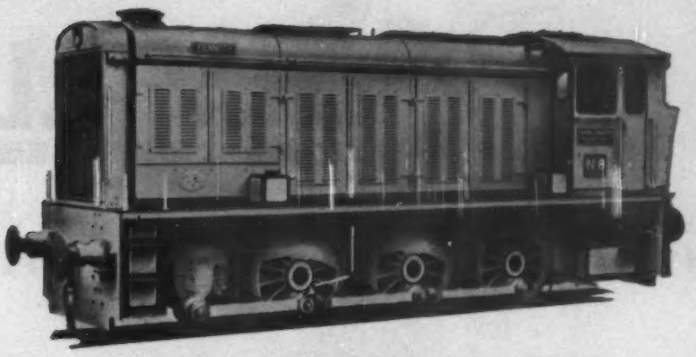

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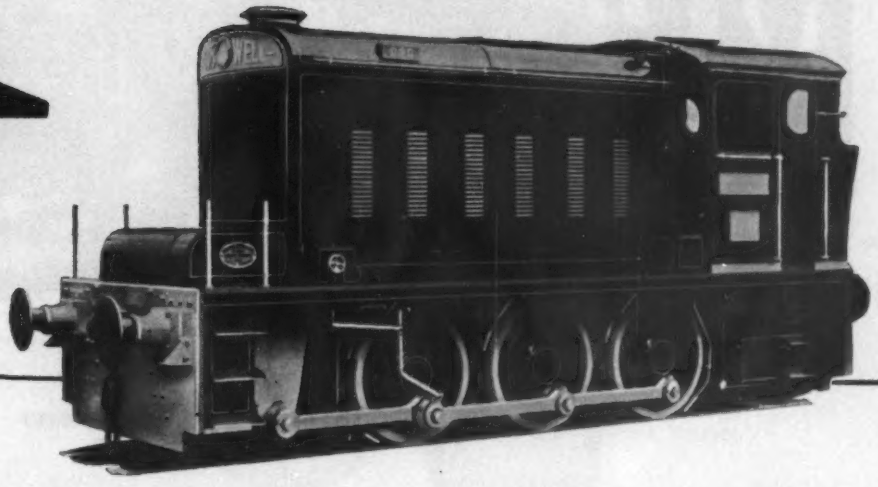

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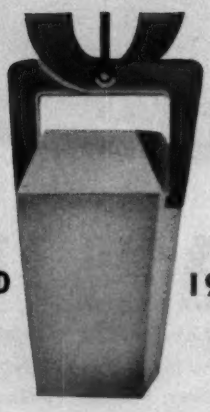

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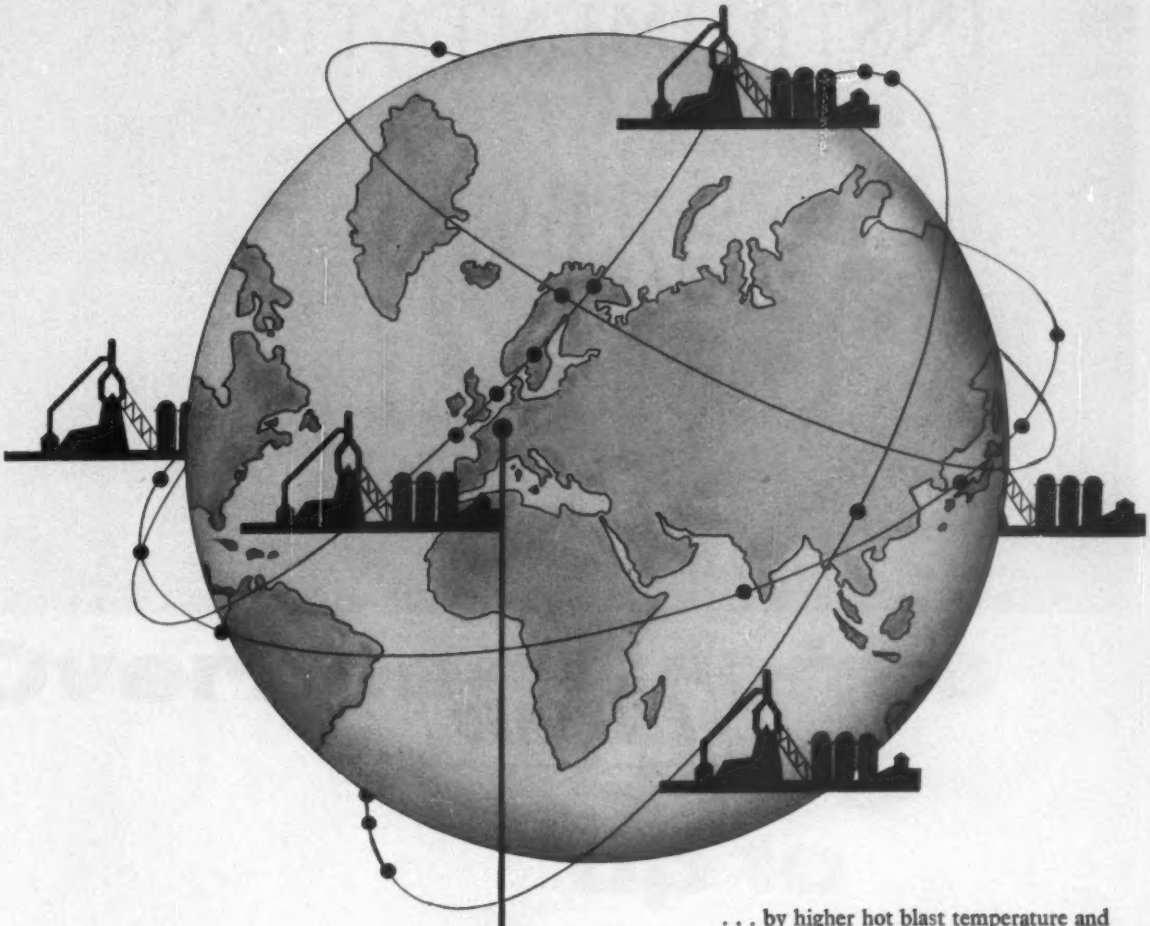

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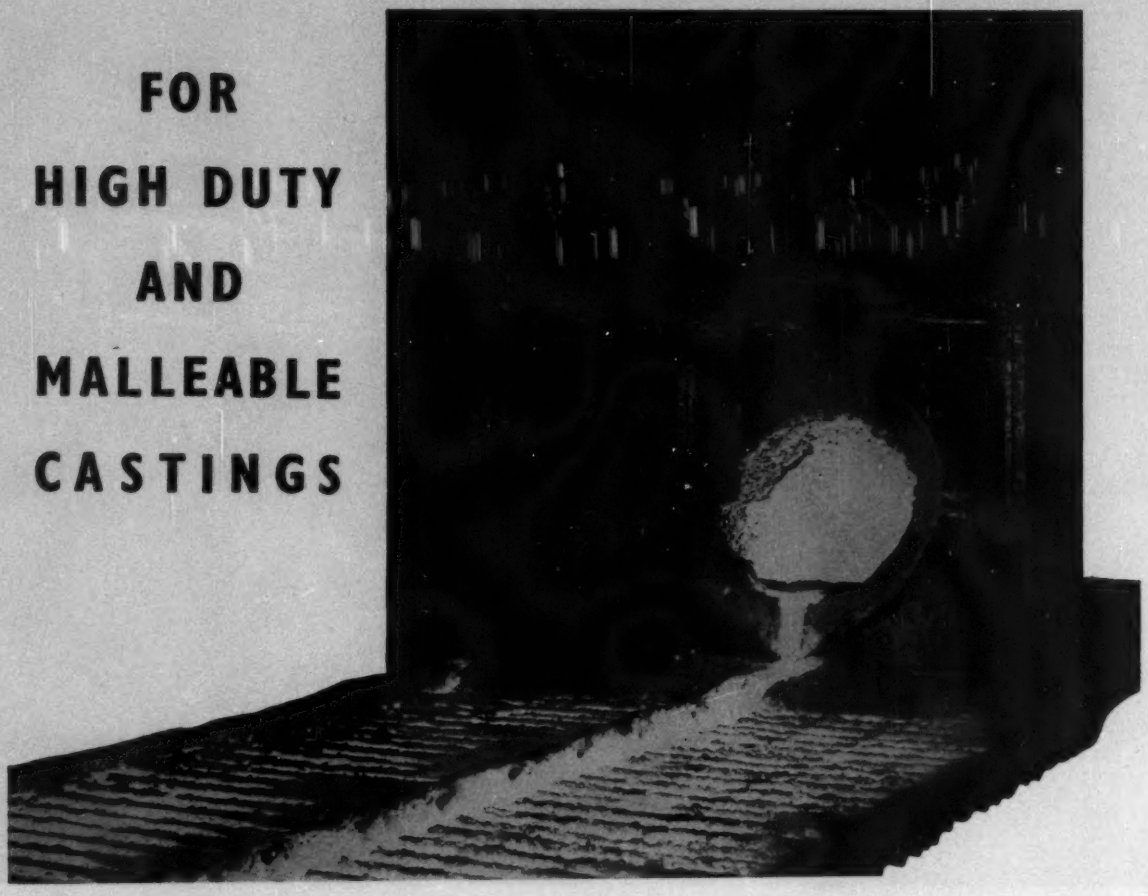

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SULPHUR %	0·06	0·07	0·08	0·05	0·08	0·07	0·06
PHOSPHORUS %	0·6–0·7	0·6–0·7	0·6–0·7	0·4–0·5	0·25	0·25	0·25
MANGANESE %	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5	0·8–1·5
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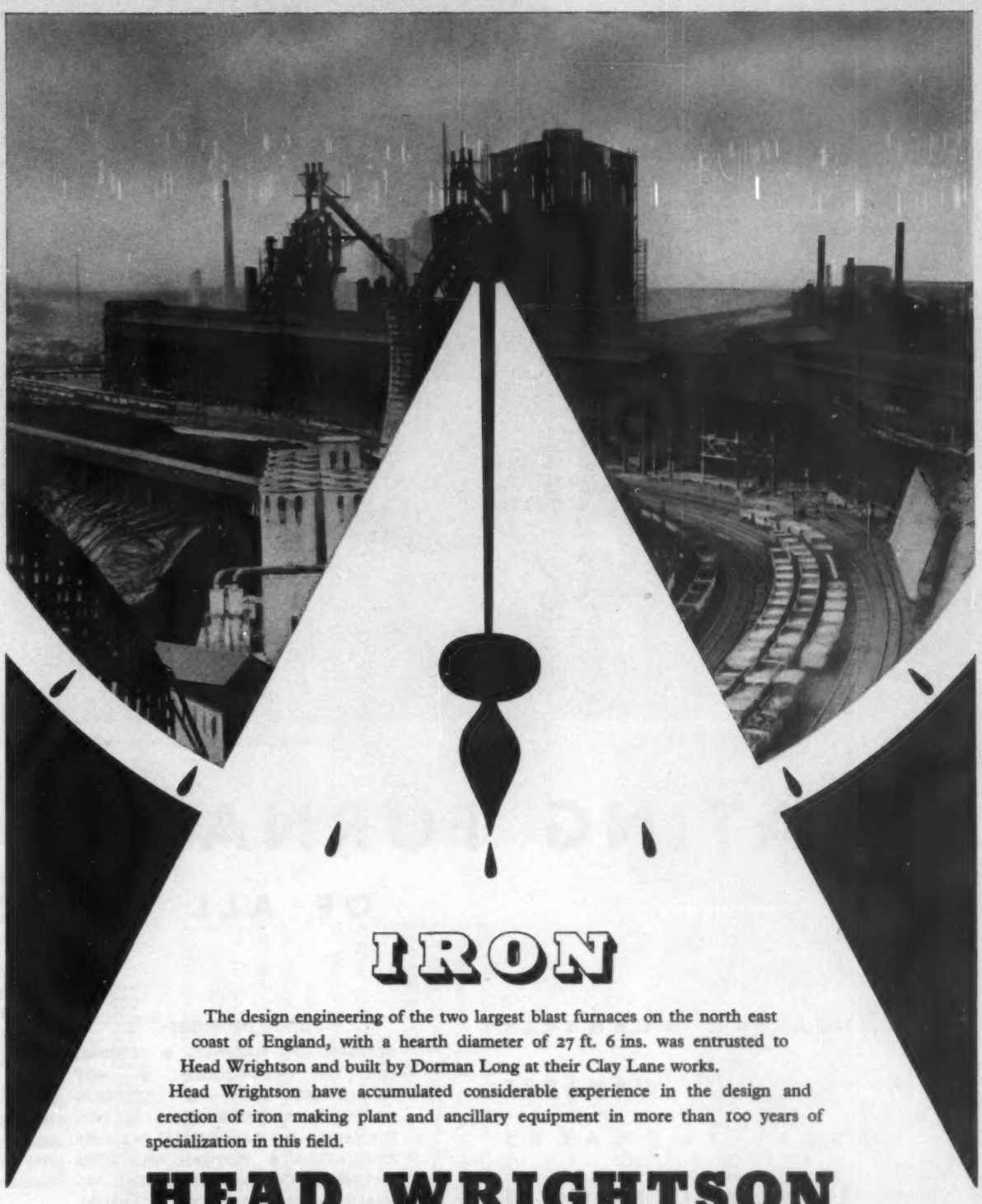

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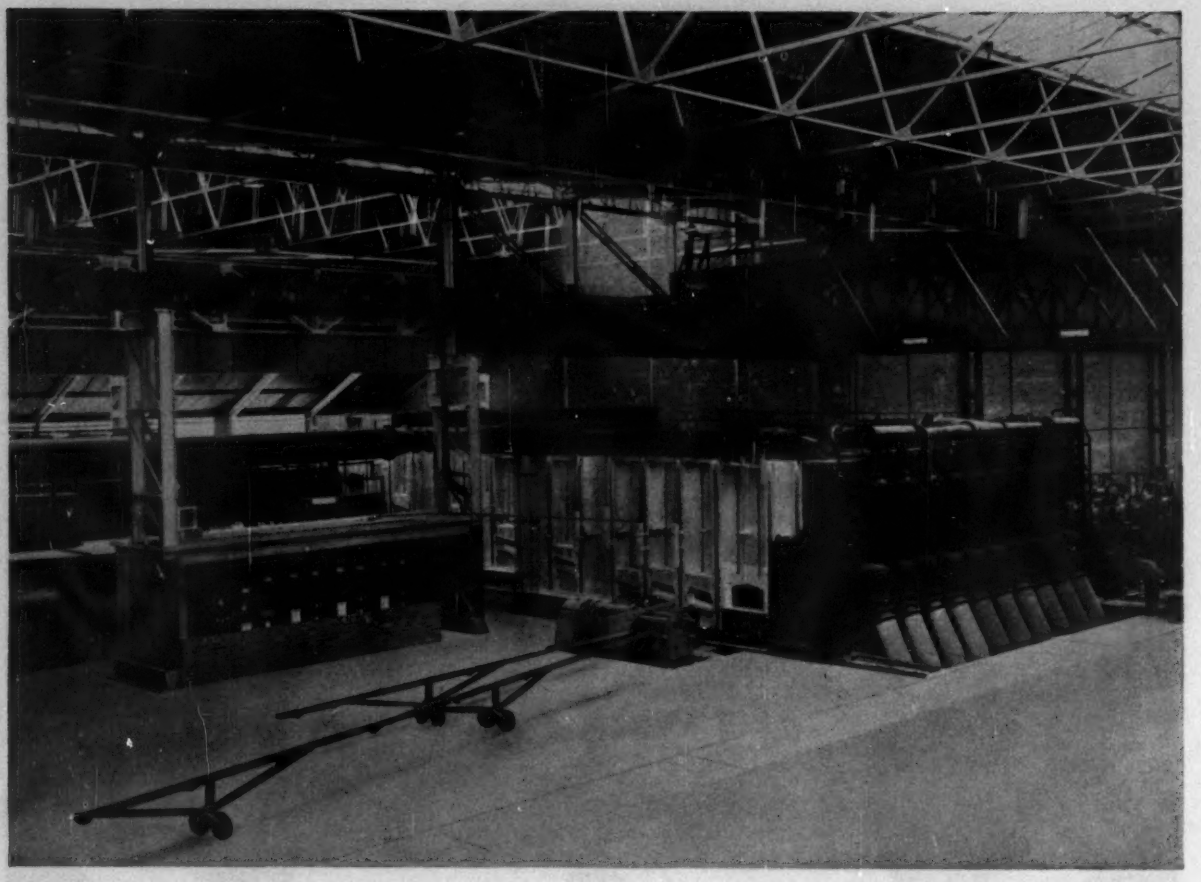

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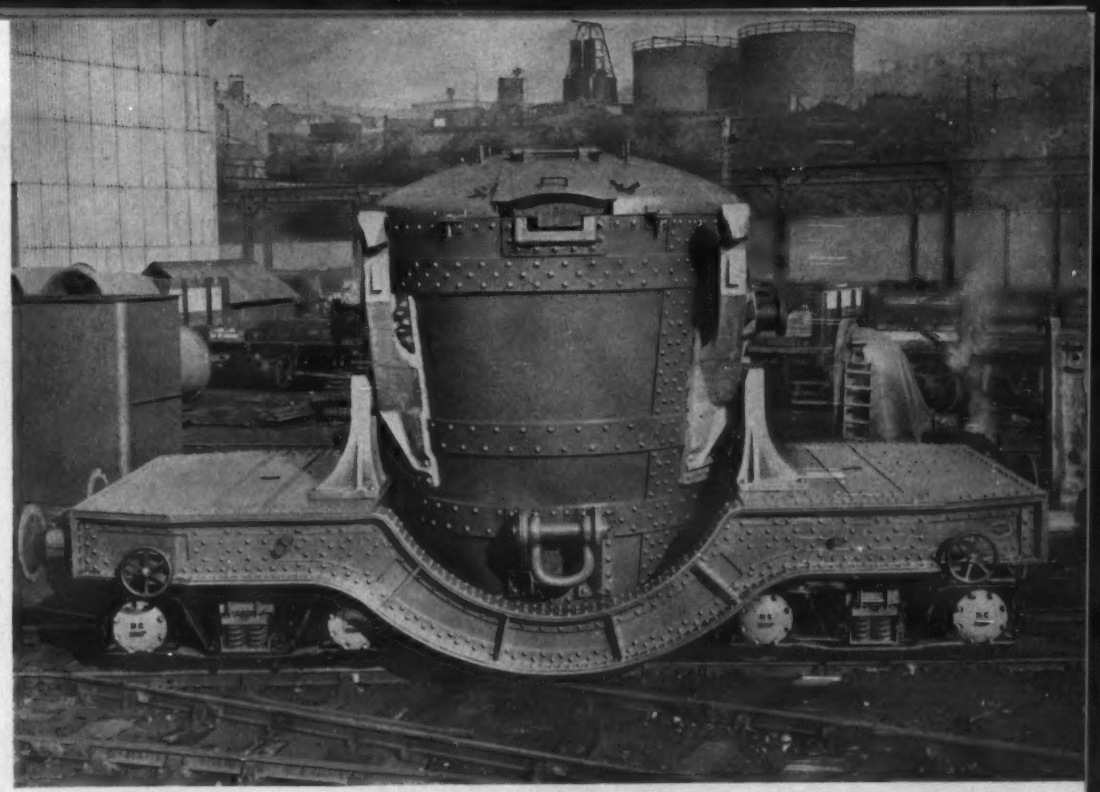

ABOVE: *60-ton capacity short pour ladle and carriage supplied to Skinningrove Iron Co. Ltd.*

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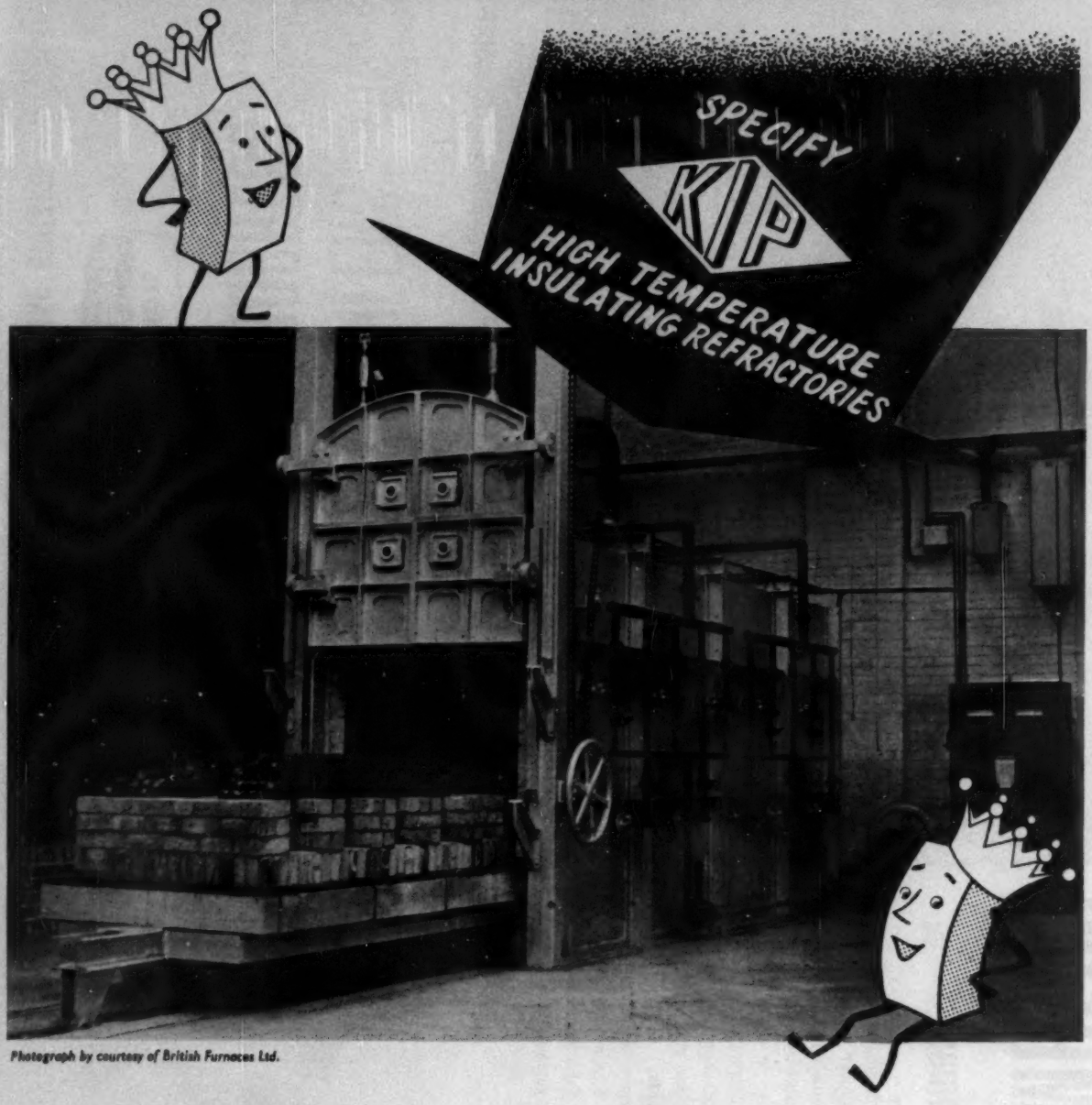

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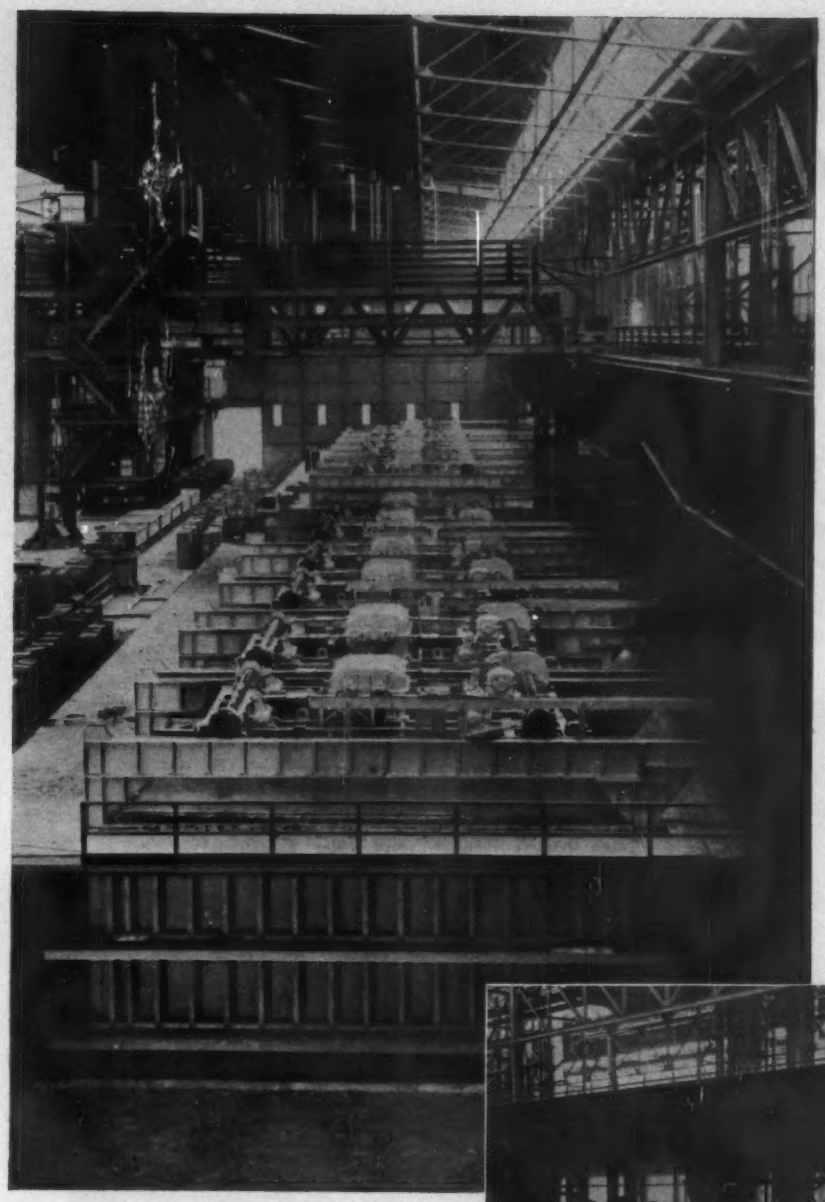

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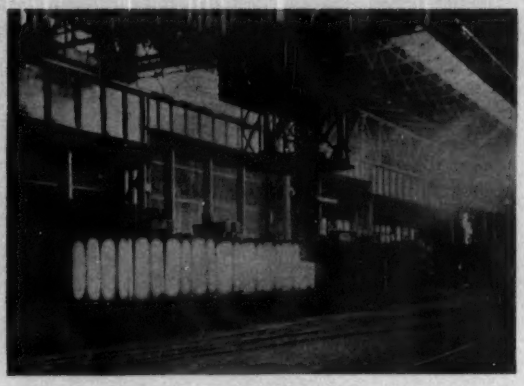

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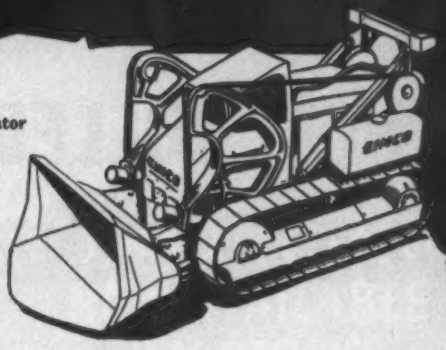

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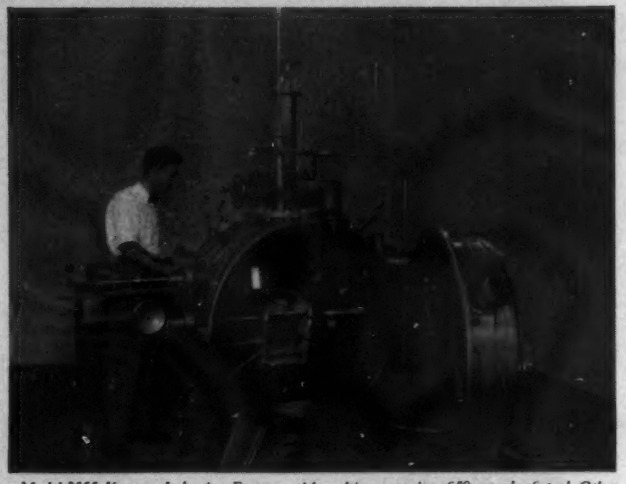

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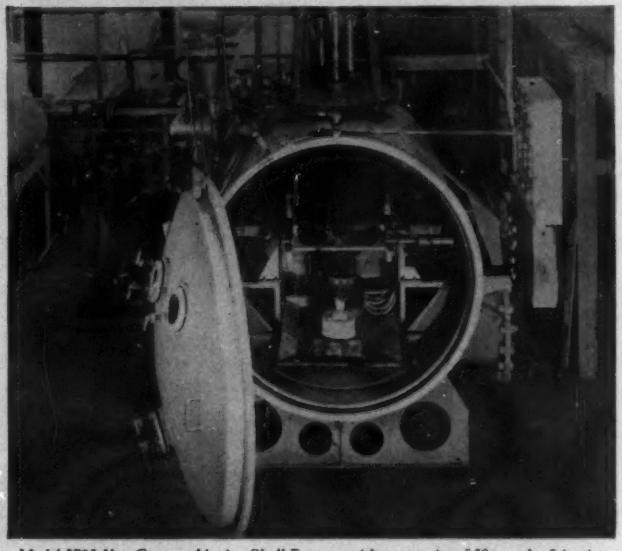

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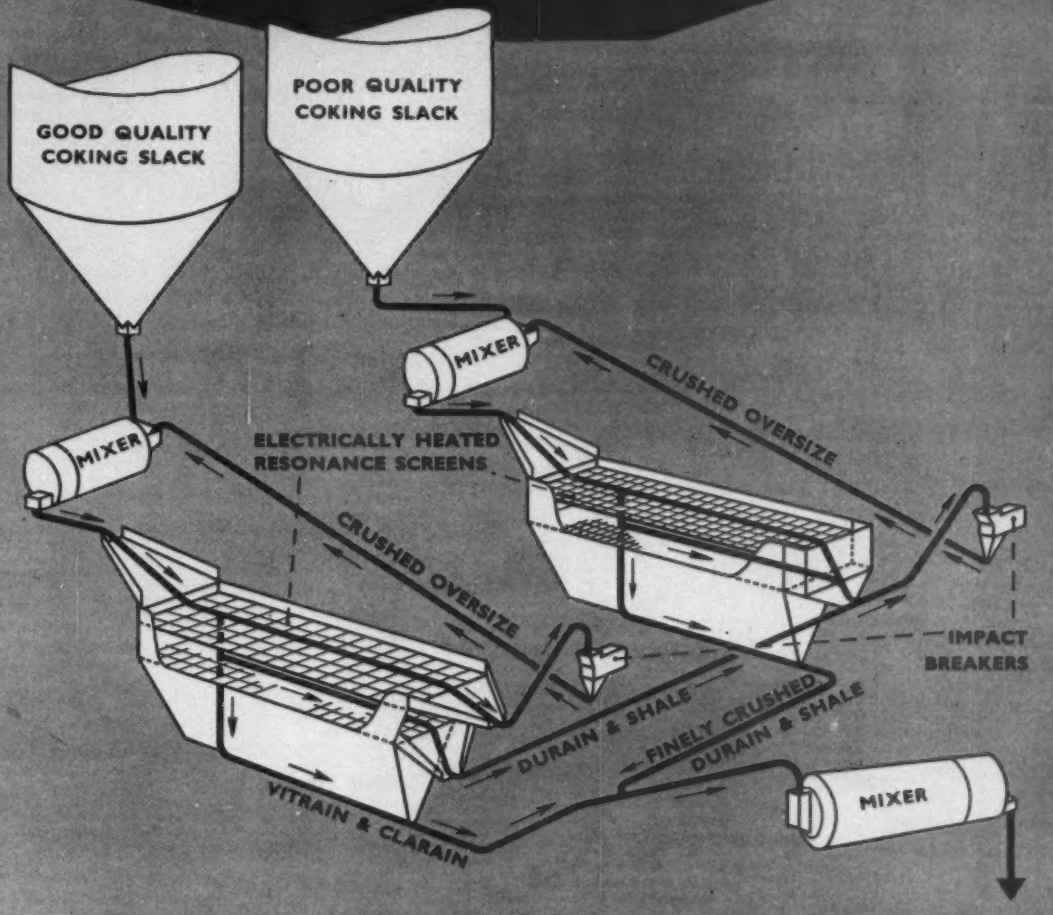

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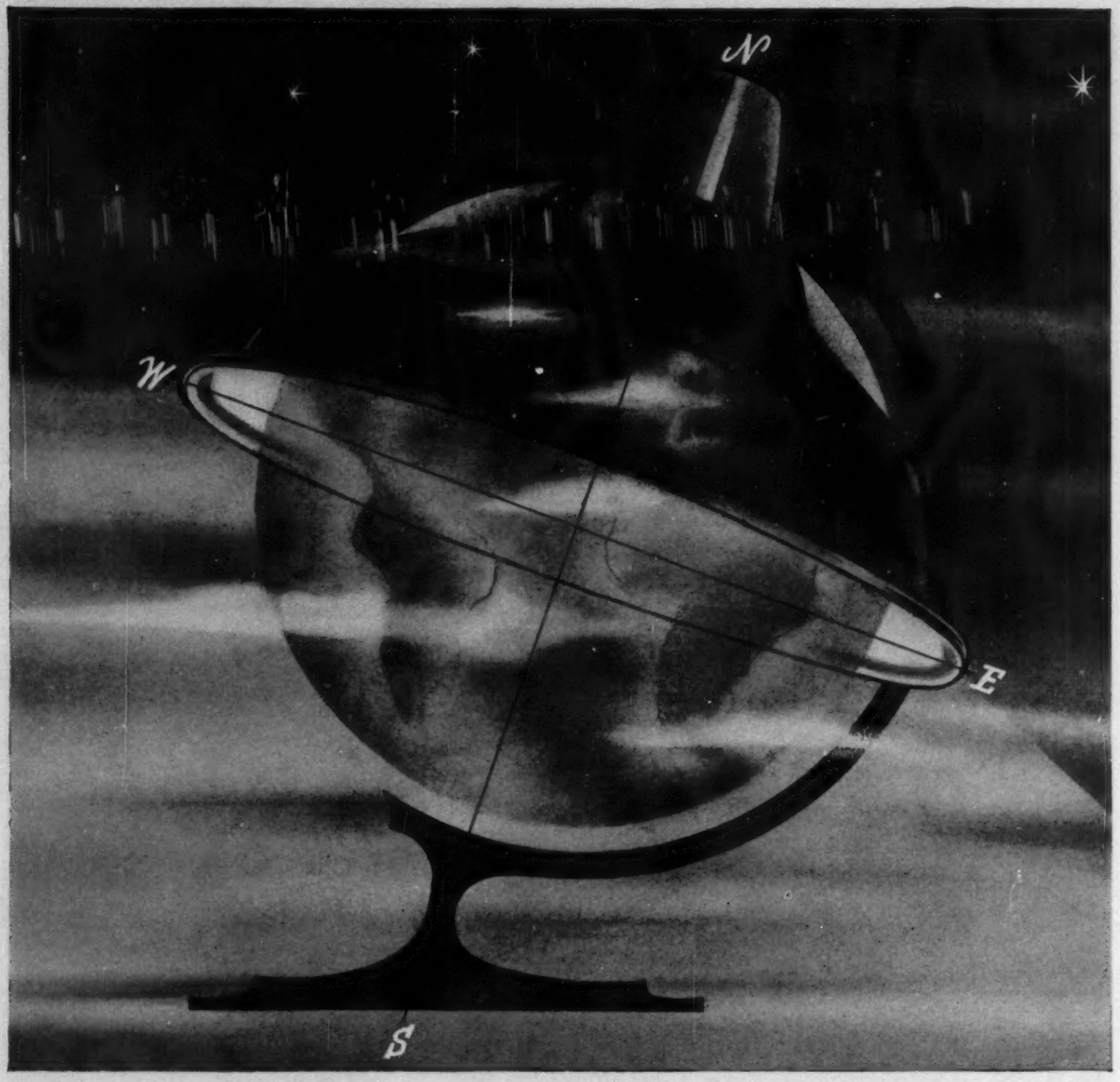

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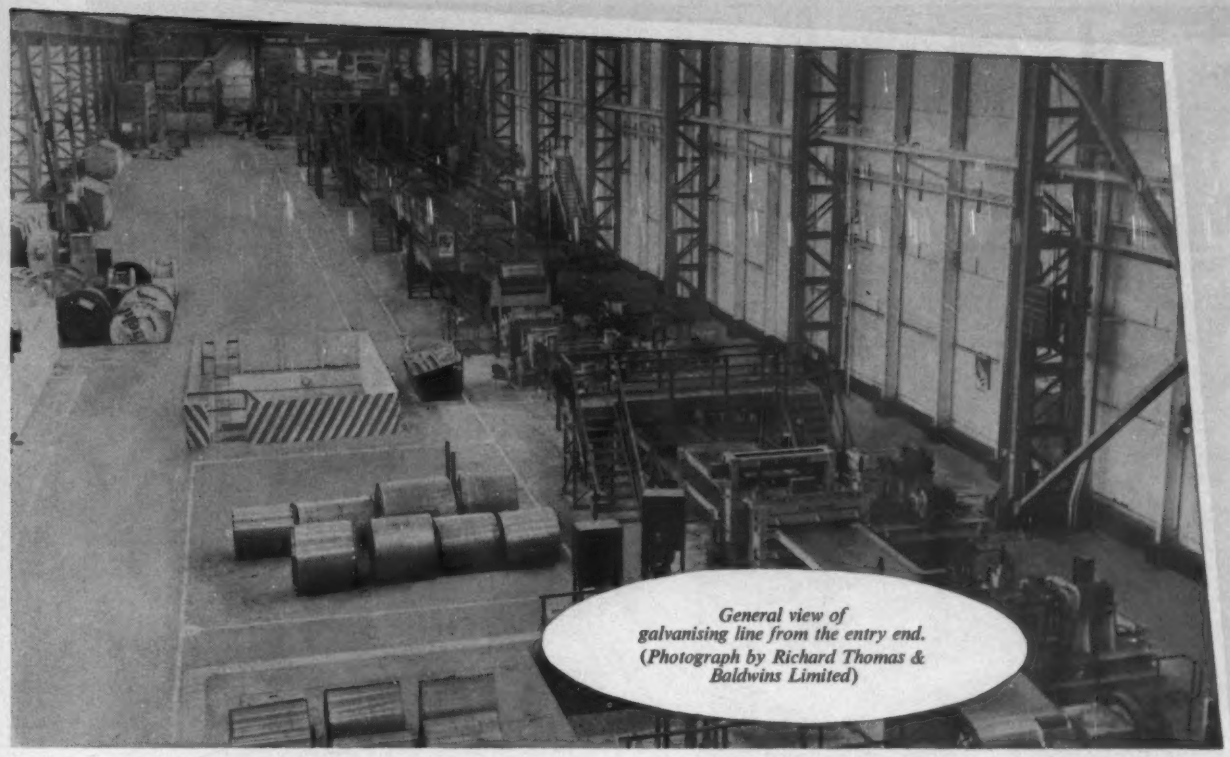

General view of galvanising line from the entry end. (Photograph by Richard Thomas & Baldwins Limited)

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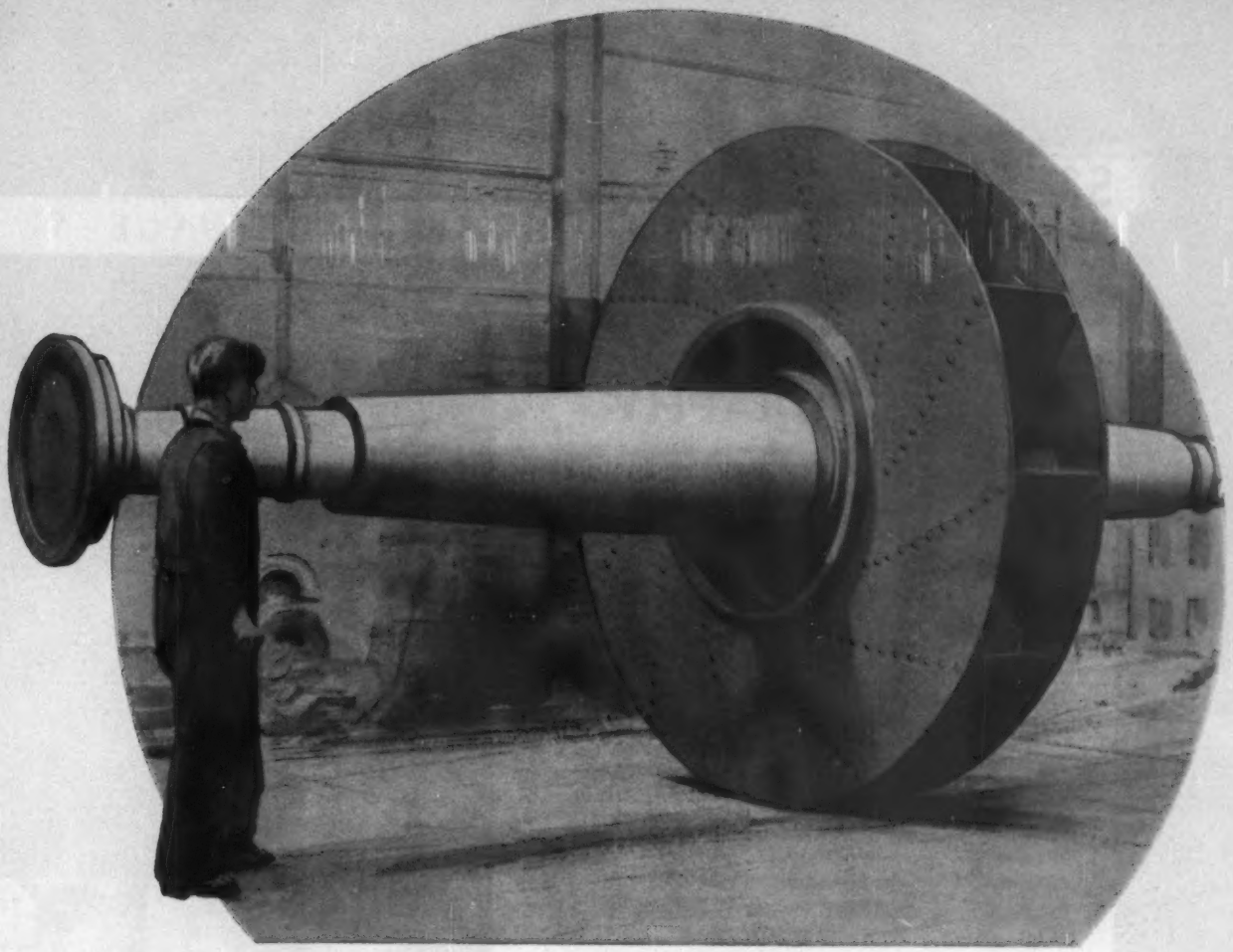

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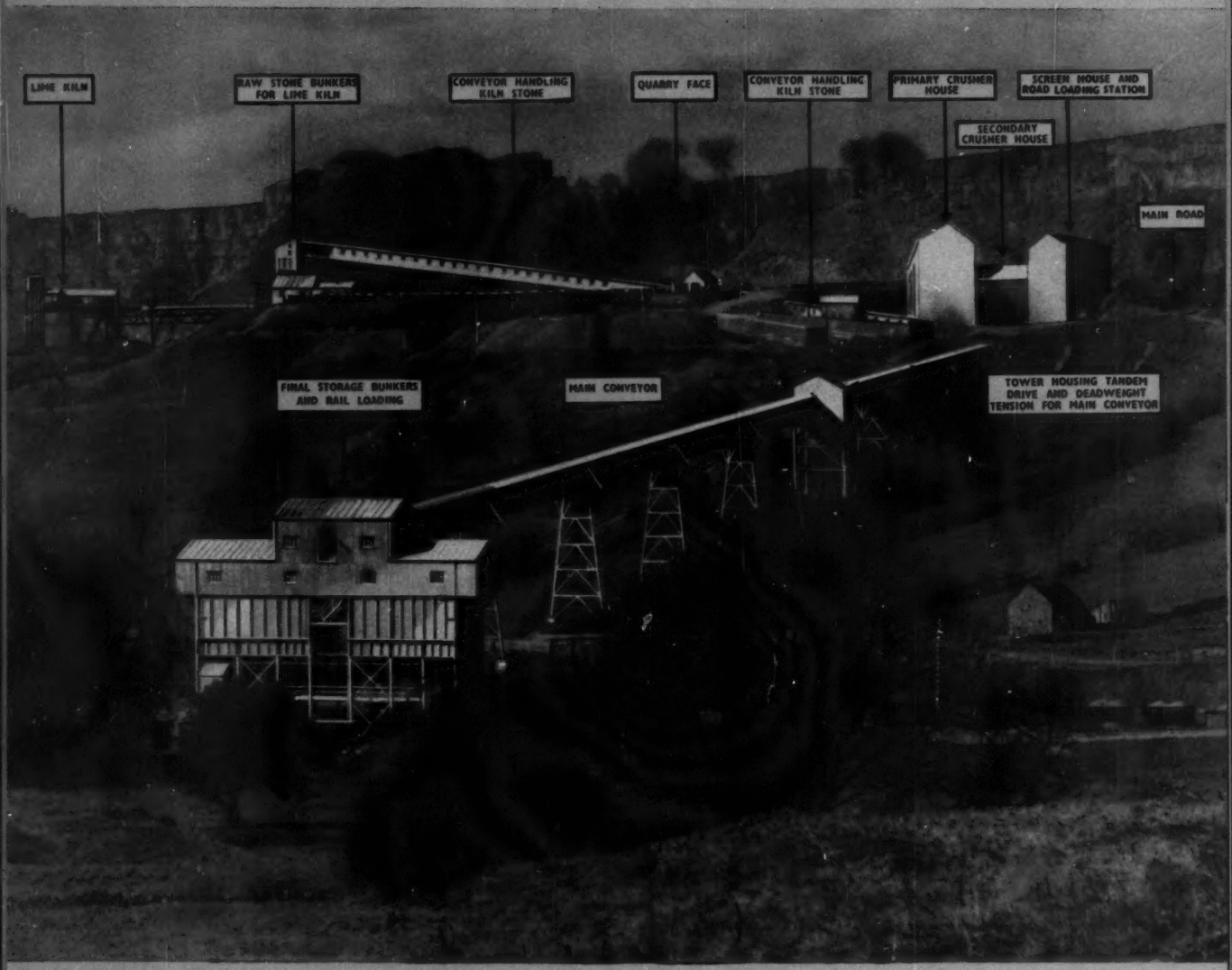
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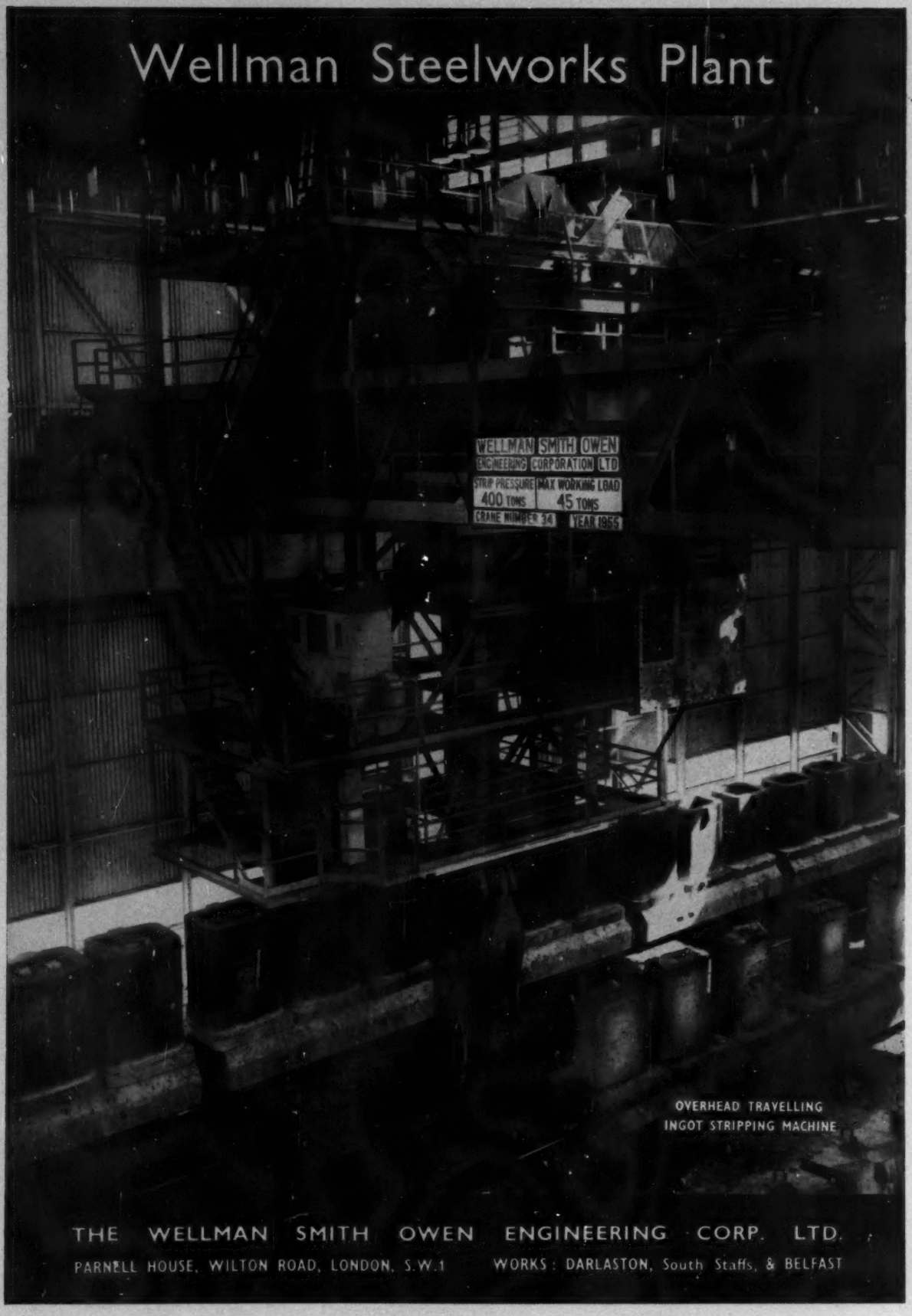
THE IRON AND STEEL INSTITUTE, 4 GROSVENOR GARDENS, LONDON, S.W.1

Wellman Steelworks Plant



OVERHEAD TRAVELLING
INGOT STRIPPING MACHINE

THE WELLMAN SMITH OWEN ENGINEERING CORP. LTD.

PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, South Staffs, & BELFAST

W. F. CARTWRIGHT, D.L., J.P., M.I.Mech.E.

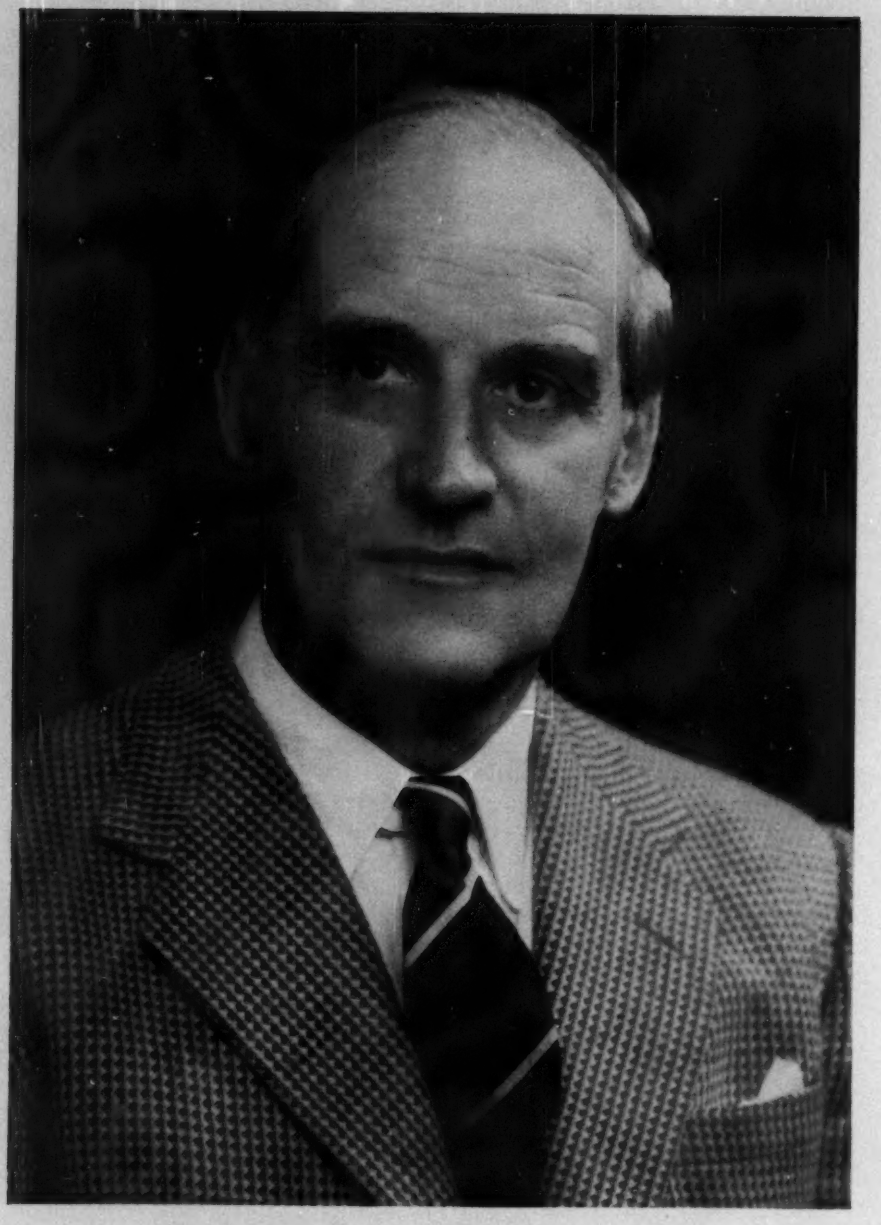
WILLIAM FREDERICK CARTWRIGHT was born in 1906 and educated at Dragon School, Oxford, and at Rugby. His technical training began in 1925, when he entered the Swindon Works of the Great Western Railway as Chief Mechanical Engineer's pupil; three years later he transferred to the Drawing Office.

He joined Guest Keen and Nettlefolds Ltd. in 1928 at their Dowlais Works, where he remained until late 1930, when he spent a year studying Continental practice at steelworks in Germany, Luxembourg, and France. Mr. Cartwright returned to the U.K. at the end of 1931 to take up the position of Assistant Works Manager at the Port Talbot Works of Guest Keen Baldwins Iron and Steel Co., Ltd.; four years later he was appointed Technical Assistant to the Managing Director, a post he held until 1940. During this period he was intimately concerned with the reconstruction and enlargement of the company's East Moors works. He was appointed Chief Engineer in 1940, and at the same time was elected to the Board of the company. Three years later he became General Manager of the Margam and Port Talbot Works.

When the Steel Company of Wales Ltd. was formed in 1949, Mr. Cartwright was elected a Director and became General Manager of the Steel Division. It was under his leadership that the development of the Abbey Works at Port Talbot took place. In 1954 he became Assistant Managing Director of the Company.

Mr. Cartwright is a member of many technical and scientific organizations, including the Institution of Mechanical Engineers (former member of council), the South Wales Institute of Engineers (member of Council), the British Iron and Steel Federation (member of council), the British Coke Research Association (member of council), the British Iron and Steel Research Association (member of council, chairman of Plant Engineering Panel, etc.), and the Institute of Fuel (Fellow). He is a member of the governing bodies of a number of educational establishments, including University College, Swansea; the Welsh College of Advanced Technology; and the University College of South Wales and Monmouthshire, Cardiff. Mr. Cartwright is also a Deputy Lieutenant of the County of Glamorgan and a Justice of the Peace.

When the Iron and Steel Engineers Group was formed in 1946, Mr. Cartwright, who joined The Iron and Steel Institute in 1936, became first Chairman of the Engineering Committee, and his drive and enthusiasm did much to establish the success of the Group. He was elected a Member of Council in 1946, and became a Vice-President nine years later. This year he was awarded the Institute's highest honour, the Bessemer Gold Medal.



W. F. Cartwright, D.L., J.P., M.I.Mech.E.

Bessemer Gold Medallist, 1958

PROCEEDINGS OF

THE INSTITUTE

Reports of Council · Meetings · Notices

Report of Council for 1957

THE COUNCIL submit this, their Annual Report and Statement of Accounts for the year 1957, to Members for their approval at the 89th Annual General Meeting of The Iron and Steel Institute.

The 88th Annual General Meeting and the Autumn General Meeting 1957 were held in London in May and September respectively. The Engineers Group held three meetings in London, of which two were concerned with air and water pollution in the iron and steel industry. A number of joint meetings were organized with Affiliated Local Societies in steelmaking districts.

ROLL OF THE INSTITUTE

The total membership at 31st December was 4990, compared with 5084 at 31st December, 1956. The decline of 94 in total membership is thought to be due to special causes. During the last 15 years, from 1942, membership has increased by 93%. No permanent change in this trend is anticipated for the time being.

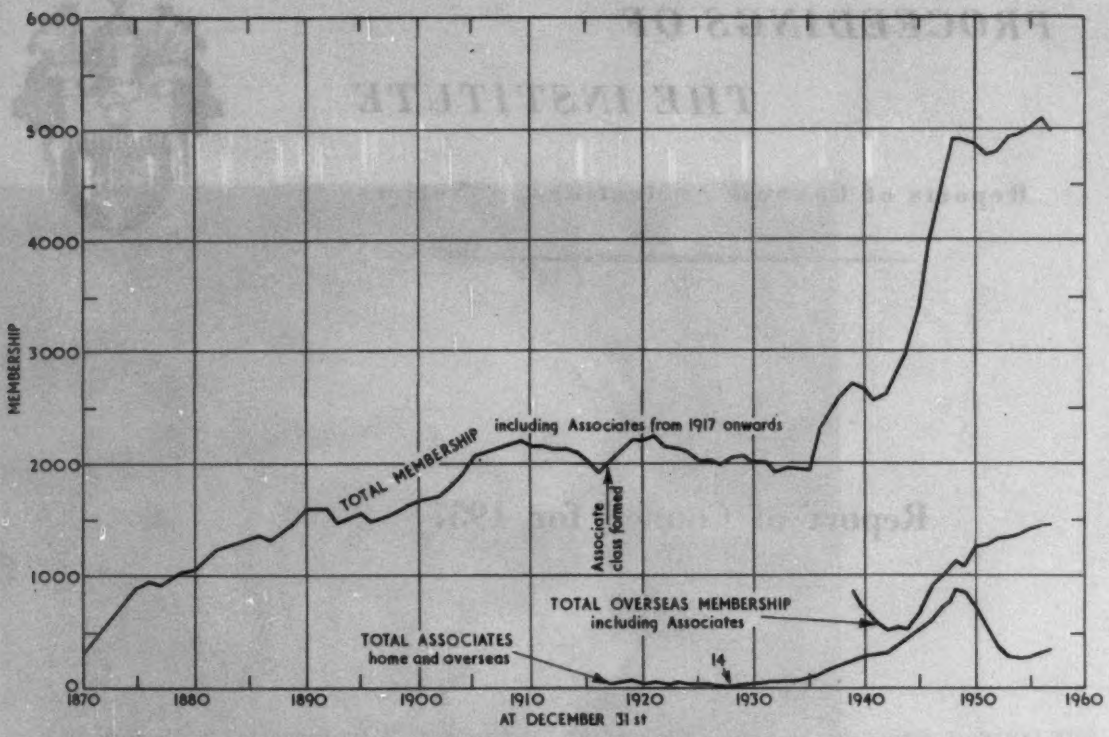
During the year, 160 Ordinary and 35 Associate Members were elected or reinstated. The deaths of 41 were reported; 192 resigned, 53 were struck off the Roll of Members, and 3 elections lapsed for non-payment of subcriptions.

An analysis of the membership at 31st December, 1957, is given in Table I, and the membership trend since the Institute was founded is shown in Fig. 1.

OBITUARY

The Council regret to announce the deaths of the following 41 Members which were reported during 1957:

BIRD, W. H. R. (Ebbw Vale)	29th August, 1957
BOND, J. A. (Scunthorpe)	9th December, 1957
BROOME, L. R. (Annan)	15th June, 1957
COWAN, W. T. (Musselburgh)	14th August, 1956
CRAIG, Sir John (Glasgow)	1st February, 1957
CROWLE, R. S. (Millom)	13th December, 1956
DAVIES, J. A. (Wolverhampton)	9th January, 1957
DAVIS, R. H. (Fonthill, Ont., Canada)	Not known
DAW, F. W. (address unknown)	Not known
DERRER, L. H. (Saulte Ste. Marie, Ont., Canada)	Not known
DORMAN, A. (London)	8th September, 1957
EVERS, W. (Liverpool)	Not known
FELGATE, L. J. W. (London)	27th April, 1957
GALLWEY, W. B. H. (Sheffield)	14th December, 1957
GILLOTT, W. M. (Sheffield)	24th July, 1957
GOOD, R. C. (Pittsburgh, Pa., U.S.A.)	11th January, 1957
HINDLEY, W. N. (Petts Wood)	13th April, 1957
JAMES, W. L. (Harleston)	2nd May, 1957
KING, C. D. (Pittsburgh, Pa., U.S.A.)	24th March, 1957
KRIEGSHEIM, H. (New York)	22nd April, 1957
MERCER, J. E. (Bulkington, Warwickshire)	31st December, 1956
MERICA, P. D. (New York)	20th October, 1957
PARRY, J. H. (Ipswich)	13th November, 1957
PRESTON, G. W. (Radlett)	17th June, 1957
RANG, E. J. (North Shields)	12th April, 1957
RIVERDALE, The Rt. Hon. Lord (Sheffield)	7th July, 1957
RUSSELL, T. F. (Sheffield)	4th December, 1957
SERVICE, T. M. (Bearsden)	5th February, 1957
SKINNER, F. J. (East Molesey)	9th December, 1956
SOTO, A. G. (Madrid)	March, 1957
STATON, R. (Sheffield)	13th February, 1957
STEEL, G. (London)	12th September, 1957
STYRI, H. (Philadelphia, Pa., U.S.A.)	13th September, 1955
TRICKER, R. E. L. (London)	22nd December, 1956
VANDESTRICK, F. A. (Seraing)	25th August, 1956
WALLIN, C. E. (Beaconsfield)	20th January, 1957
WALTERS, W. I. (Croydon)	13th April, 1957
WHALE, R. (London)	12th April, 1957
WRAGG, B. (Sheffield)	2nd February, 1957
WRIGHT, H. E. (Sheffield)	13th January, 1957
ZEDNIK, V. (Ostrava, Czechoslovakia)	1953



Note: The Associate class was renamed Associate Member in 1949

Fig. 1—Variation in Membership since the foundation of the Institute in 1869

Table I

MEMBERSHIP OF THE IRON AND STEEL INSTITUTE AT 31st DECEMBER, 1957, AND COMPARISON WITH 1956

	Membership at 31st December, 1957													1956		
	Ordinary Membership		Joint Membership with								Total Membership		Grand Totals	Total Membership		Grand Totals
			Institute of Metals		Institution of Metallurgists		Both Institute and Institution		Totals							
	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas	Home	Overseas		Home	Overseas	
Patron	1	...	...	...	...	...	...	...	...	...	1	...	1	1	...	1
Members:																
Hon. Vice-Presidents	6	9	1	1	...	...	...	...	1	1	7	10	17	7	10	17
Hon. Members	3	7	...	1	...	...	...	1	...	2	3	9	12	4	9	13
Non-paying Members	5	1	...	...	...	...	...	...	...	...	5	1	6	5	1	6
Life Members	58	38	3	6	7	...	5	1	15	7	73	45	118	76	41	117
Ordinary Members	1777	864	443	373	548	57	451	65	1442	495	3219	1359	4578	3267	1351	4618
Total (Members)	1850	919	447	381	555	57	456	67	1458	505	3308	1424	4732	3360	1412	4772
Associate Members	49	12	159	15	11	2	10	...	180	17	229	29	258	278	34	312
Total (both classes)	1899	931	606	396	566	59	466	67	1638	522	3537	1453	4990	3638	1446	5084

Sir John Craig, C.B.E., joined the Institute in 1917, became a Member of Council in 1922, and a Vice-President in 1928; he served as President from 1940 to 1942 and was made an Honorary Member in 1956. Mr. Arthur Dorman's membership dated from 1906; he was elected a Member of Council in 1925, a Vice-President in 1932, and President for two years from 1944 to 1946. Mr. W. L. James became a Member in 1935; he had been a Member of Council since 1954, having previously served as an Honorary Member of Council from 1952 to 1954, during his presidency of the Lincolnshire Iron and Steel Institute. Mr. Gerald Steel, C.B.E., became a Member in 1942, a Member of Council in 1944, and a Vice-President in 1948; at the time of his death he was President-Elect of the British Iron and Steel Federation.

Mr. W. H. R. Bird had been an Honorary Member of Council during his presidency of the Ebbw Vale Metallurgical Society from 1956 to 1957. Mr. J. A. Bond was a Williams Prizeman in 1951.

The following had been Members for 40 years or more: Mr. H. E. Wright (1918), Mr. W. M. Gillott (1913), Mr. B. Wragg (1910), Mr. T. M. Service, C.B.E. (1906), The Rt. Hon. Lord Riverdale of Sheffield, G.B.E. (1905), and Mr. F. W. Daw (1897); and the following had been Members for over 35 years: Mr. J. A. Davies (1922), Dr. P. D. Merica (1921), Mr. H. Styri and Mr. C. E. Wallin (1920), and Mr. T. F. Russell (1919).

CHANGES ON THE COUNCIL

President-Elect

It was announced at the Autumn General Meeting, 1957, that the Council had unanimously decided to nominate Mr. C. R. Wheeler, C.B.E. (*Vice-President*), for election as President at the Annual General Meeting in 1958, to hold office for one year.

Other Changes

During 1956, Mr. D. F. Campbell, Mr. I. F. L. Elliot, and Mr. G. H. Latham were elected Honorary Vice-Presidents, and Mr. E. J. Pode was elected a Vice-President. Mr. E. W. Colbeck and Lt. Cdr. G. W. Wells, R.N. (RETD.), were elected Members of Council.

Dr. L. B. Pfeil, O.B.E., F.R.S., President of The Institute of Metals, agreed to serve as an Honorary Member of Council during his period of office, following Major C. J. P. Ball.

The following agreed to serve as Honorary Members of Council during their Presidencies of the Affiliated Local Societies named: Mr. T. W. Thursfield (Cleveland Institution of Engineers, following Mr. F. B. George); Mr. N. S. Angus (East Midlands Metallurgical Society, newly affiliated); Mr. J. T. Mills (Ebbw Vale Metallurgical Society, following Mr. W. H. R. Bird); Mr. P. A. Green (Leeds Metallurgical Society, following Mr. A. Lenton); Mr. A. H. Norris (Lincolnshire Iron and Steel Institute, following Mr. C. T. Thomas); Mr. J. S. W. Graham (Liverpool Metallurgical Society, following Mr. W. Rose); Dr. K. M. Entwistle (Manchester Metallurgical Society, following Mr. G. A. Cottell); Mr. C. I. F. Mackay (Newport and District Metallurgical Society, continuing Presidency); Mr. H. Brooke Freeman (North Wales Metallurgical Society, following Mr. R. L. Willott, D.S.O., O.B.E., T.D.); Mr. R. C. Baker (Sheffield Metallurgical Association, following Mr. P. Jubb); Mr. E. D. Bool (Sheffield Society of Engineers and Metallurgists, following Mr. L. K. Everitt); Mr. G. Parkin (Staffordshire Iron and Steel Institute, following Mr. A. Biddulph); Mr. J. S. Caswell (Swansea and District Metallurgical Society, following Mr. R. Walker); Dr. H. Harris (West of Scotland Iron and Steel Institute, following Mr. S. Thomson).

Mr. E. J. Bradbury and Mr. W. E. Bardgett represent The Institution of Metallurgists on the Council, following Mr. R. S. Brown, M.B.E., and Dr. L. B. Pfeil, O.B.E., F.R.S.

In accordance with Bye-Law 10, the following names of Vice-Presidents and Members of Council due to retire at the Annual General Meeting, 1958, were announced at the Autumn General Meeting, 1957:

Vice-Presidents: Mr. W. F. Cartwright, Sir Charles Goodeve, O.B.E., D.SC., F.R.S., Mr. N. H. Rollason.

Members of Council: Dr. J. W. Jenkin, Mr. F. H. Saniter, Mr. T. Jolly, Mr. R. A. Hacking, O.B.E., Mr. W. C. Bell.

AWARDS AND PRIZES

The *Bessemer Gold Medal* for 1957 was awarded to DR. R. DURRER, Honorary Vice-President (Ludwig von Roll'schen Eisenwerke A.G.) in recognition of his distinguished contribution to the development of iron and steelmaking processes, and especially his pioneer work in the application of electricity to smelting and in the use of oxygen in iron and steelmaking.

The *Sir Robert Hadfield Medal* for 1957 was awarded to MR. J. GLEN (Colvilles Ltd.) in recognition of his important contribution to the study of the deformation of steel at elevated temperatures, which has led to a more reliable interpretation of creep data.

The *Andrew Carnegie Silver Medal* for 1956 was presented to DR. J. WILCOCK (University of Liverpool) for his report on "Reactions involved in the First-stage Graphitization of Iron–Carbon–Silicon Alloys" (*Journal*, 1956, vol. 182, pp. 38–43). His co-author, Professor W. S. Owen, was not eligible for an award.

A *Williams Prize* for 1956 of £100 was presented to MR. H. H. ASCOUGH (Steel Company of Wales Ltd.) in respect of his paper "Maximum Utilization and Problems of Wide-Strip Rolling and Sheet Finishing Equipment" (*Journal*, 1956, vol. 184, pp. 24–46).

A *Williams Prize* for 1956 of £50 was presented to MR. R. H. SLADE (Steel Company of Wales Ltd.) for his paper "Soaking Pit Practice at the Abbey Works of the Steel Company of Wales Ltd." (*Journal*, 1956, vol. 182, pp. 3–9).

An *Ablett Prize* for 1956 of £100 was presented to MR. R. M. L. ELKAN (The Loewy Engineering Co., Ltd.) for his paper "Modern Forging Presses and Their Control" (*Journal*, 1956, vol. 182, pp. 200–215). His co-author, Mr. J. T. Lewis, was not eligible for an award.

ANDREW CARNEGIE RESEARCH GRANTS

During 1957 the following grants were made from the Andrew Carnegie Research Fund:

R. E. M. BALL (Imperial College, London): £435 for a research on the effect of stored energy on the fracture characteristics of certain steels.

I. M. DAVIDSON (Liverpool University): £300 for a research on the activity of ferrous oxide in silicate slags.

T. GLADMAN (Sheffield University): £400 for a research on the effect of hydrogen on transformations in alloy steels.

J. C. HUMPHREYS (Liverpool University): £300 for a research on carbide constituents in iron–carbon–silicon alloys.

K. A. SALMON (Sheffield University): £400 (second grant) for a research on the kinetics of the transfer of sulphur between iron and slag.

J. S. WHITE (Liverpool University): £200 for a research on the bainite reaction.

MOND NICKEL FELLOWSHIPS

Mr. F. H. Saniter continued to represent the Institute on the Mond Nickel Fellowships Committee.

The Committee made the following Awards for 1957:

R. J. D. ACHESON (Mufulira Copper Mines Ltd.) to study the extraction and refining processes for copper and allied metals with particular reference to economic aspects.

E. J. WILLIAMS (John Summers and Sons Ltd.) to study the research and production techniques, quality control and metallurgy of high-quality low-carbon strip steel in the United Kingdom, the Continent, and the United States.

MEETINGS

Annual General Meeting, 1957

The 88th Annual General Meeting was held in London on Wednesday and Thursday, 22nd and 23rd May, 1957, at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. After the Report of Council and Accounts for 1956 had been approved, and other formal business transacted, Dr. H. H. Burton, C.B.E., inducted Mr. A. H. Ingen-Housz into the Chair. The new President then delivered his Presidential Address on the "Birth of an Industry" (*Journal*, 1957, vol. 186, June, pp. 153–166).

The proceedings of the meeting are recorded on pp. 385–387 of the *Journal* for August, 1957, and the report of the discussions on pp. 216–238 of the *Journal* for November, 1957.

A Dinner for Members was held at Grosvenor House on Wednesday, 22nd May, at which the Rt. Hon. the Earl of Halsbury and H.E. Dr. D. U. Stikker, G.B.E., the Royal Netherlands Ambassador, were the principal guests.

Autumn General Meeting, 1957

The Autumn General Meeting of the Institute was held at the Offices of the Institute on Tuesday, 24th September, with the President in the Chair. Proceedings of the Meeting are reported on pp. 1–3 of the *Journal* for January, 1958.

The Meeting was followed by a lecture on "Future Engineering Developments of the Gas-Cooled Nuclear Reactor" by Dr. J. M. Kay, Professor of Nuclear Power at the Imperial College of Science and Technology, London. The lecture was given at the Royal Institution and is published on pp. 3–8 of the *Journal* for January, 1958.

Joint Meeting in Sheffield

A Joint Meeting with the Sheffield Society of Engineers and Metallurgists and the Sheffield Metallurgical Association was held at Sheffield University on Thursday, 28th November. Dr. H. H. Burton (Past-President) was in the Chair. The programme of the meeting is given on p. 55 of the *Journal* for September, 1957.

The Tenth Hatfield Memorial Lecture

The Tenth Hatfield Memorial Lecture, on "The Mechanism of Formation of Banded Structures," was given by Professor Paul Bastien, Directeur Scientifique, Etablissements Schneider et Société des Forges et Ateliers du Creusot, on the evening of Thursday, 28th November, in the Firth Hall of the University of Sheffield. Dr. J. Whittaker, F.R.S., Vice-Chancellor of Sheffield University, was in the chair. The lecture was published on pp. 281–291 in the *Journal* for December, 1957.

IRON AND STEEL ENGINEERS GROUP

Mr. W. M. Larke continued to serve as Chairman of the Iron and Steel Engineers Group. The Engineering Committee which organizes the activities of the Group was composed of the following members as from June, 1957:

Chairman

Mr. W. M. LARKE

Members

Mr. R. CAMERON	Mr. D. L. CAMPBELL
Sir H. CLAY, BT.	Mr. W. A. J. DINWOODIE
Mr. D. R. EASTWOOD	Mr. F. B. GEORGE
Mr. R. A. LAKE	Mr. S. A. LEWITT
Mr. H. M. MORGAN	Mr. J. MORGAN
Mr. C. E. H. MORRIS	Mr. D. E. MOXEY
Mr. C. M. SLOCOMBE	Mr. G. WARRIOR

Ex-Officio

Mr. A. H. INGEN-HOUSZ, Mr. W. BARR, O.B.E.
Dr. H. R. MILLS

The Group held a one-day meeting in London in April devoted to "Lubrication in Iron and Steelworks." A Meeting of Junior Engineers was held in March at Chester, with visits to the works of John Summers and Sons Ltd., and the Metropolitan-Vickers Electrical Company Ltd. at Manchester.

The Group also organized a two-day meeting in September on "Air Pollution in the Iron and Steel Industry" and a two-day meeting in December on "Water Pollution in the Iron and Steel Industry": both these meetings were held in London. The papers and discussions relating to these two meetings are being published in the Special Report Series of the Institute.

POWDER METALLURGY JOINT GROUP

The success of the Second Symposium on Powder Metallurgy held in 1954 had shown the need for a forum in the United Kingdom in which topics of peculiar interest to powder metallurgy specialists could be discussed. Accordingly, as announced at the Annual General Meeting in May, 1957, a Powder Metallurgy Joint Group has been organized in collaboration with The Institute of Metals, to operate within the framework of the two Institutes. Dr. Ivor Jenkins is the Chairman, and Mr. D. A. Oliver, C.B.E. (Member of Council) is the Vice-Chairman, the other representatives of The Iron and Steel Institute on the Joint Committee being Dr. W. D. Jones, Dr. T. Raine, and Dr. S. M. Trent.

The Inaugural Meeting was held at Church House, Westminster, on 4th December, 1957, when Dr. Jenkins was in the Chair. An account of the meeting will be published in the *Journal*.

BRITISH NUCLEAR ENERGY CONFERENCE

Early in the year, the Institute, together with The Institute of Metals, joined the British Nuclear Energy Conference. The Institutes have three representatives each on the Board of the Conference.

The purpose of the Conference is to organize meetings to discuss papers on various aspects of nuclear energy and related subjects, and to co-ordinate into a joint programme meetings held by the constituent institutions. Members of The Iron and Steel Institute are entitled to buy the quarterly *Journal of the British Nuclear Energy Conference* at a reduced rate and to attend the meetings on nuclear energy subjects sponsored by any of the participating Institutions.

Members of the collaborating institutions were invited to attend one of the afternoon sessions of the Institute's Autumn Meeting and the lecture on 24th September.

PUBLICATIONS

Journal

The *Journal* was again published in twelve monthly parts, comprising Volumes 185, 186, and 187. Indexes and binding cases are being prepared.

Special Reports

One Special Report, "Forgemasters' Meeting, 1954" (No. 60), was published.

Bibliographies

Bibliography No. 21, "The Continuous Casting of Steel," was issued during 1957.

Translation Service

During the first four months of the year seventeen translations (Nos. 515–531) of foreign articles were issued at the old price of £1 each.

The Institute has, at the suggestion and with the assistance of the British Iron and Steel Research Association and after consultation with the British Iron and Steel Federation, organized a *Co-operative Translation Service*. This is being operated by a number of companies in the steel industry and is being administered by the Institute on their behalf. The object of the service is to meet the growing need for translations of foreign technical and scientific papers. The intention is to make more technical translations promptly available to Members of the Institute and of the British Iron and Steel Research Association and to avoid duplication. One hundred and forty-eight (Nos. 532–679) were issued between 1st May and 31st December, 1957.

Translations may be purchased by non-members. Requests for the preparation of translations are welcomed. If suitable, such translations are incorporated into the scheme. In other cases quotations for the cost of preparation will be supplied. Eleven translations not included in the co-operative scheme were supplied at the request of Members during 1957.

News of new translations available and in preparation is published in the Institute's *Journal* (monthly), B.I.S.R.A. *Report List* (every six weeks), and the British Iron and Steel Federation *Review of British and Foreign Press* (fortnightly). The translations are on sale at the Institute.

Handbook and List of Members

The Handbook and List of Members, 1957, was issued to all Members during the year. In addition to the List of Members arranged alphabetically and topographically, it contained information on the constitution, history, and activities of the Institute.

Other Publications

At the request of the Institute of British Foundrymen, the Institute undertook, as from 1st January 1957, to assist in the production of a new journal, *The British Foundryman*. It also continued to assist in the production of the *British Welding Journal* and the *Transactions of the Society of Instrument Technology*.

JOINT LIBRARY AND INFORMATION DEPARTMENT

In 1957, 13,847 publications were borrowed from the Joint Library of The Iron and Steel Institute and The Institute of Metals. This represents an increase of 1157, or about 9%, over the number borrowed in 1956. In addition, nearly one thousand publications were issued to members of the staff of the two Institutes. During 1957, 351 new text books were acquired (401 in 1956); the Council wishes to thank authors who presented copies of their books and papers.

Photographic copies of documents can be supplied to members. During 1957, 187 photocopies and 51 microfilms were prepared (211 and 45 in 1956); of these, about two-thirds of the photocopies and all the microfilms were sent abroad.

The Information Department, without encroaching on the field of the metallurgical consultant, seeks to answer a wide variety of enquiries, especially by reference to the scientific and technical literature. During the year Members, Government Departments, Universities, Research Associations and commercial organizations made frequent use of these services, which included the provision of numerous bibliographies of varying lengths.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

The close co-operation with the British Iron and Steel Research Association which had existed since the formation of the Association was continued and progress made in developing certain extensions and improvements.

RELATIONS WITH OTHER SOCIETIES AND ORGANIZATIONS IN GREAT BRITAIN AND OVERSEAS

Friendly relationships were maintained with many scientific and technical societies at home and overseas, including especially The Institute of Metals, The Institution of Metallurgists, and the West of Scotland Iron and Steel Institute. Friendly co-operation also continued with the Iron and Steel Board, the British Iron and Steel Federation, and the British Iron and Steel Research Association.

Affiliated Local Societies in Great Britain

During the year, the East Midlands Metallurgical Society became affiliated with the Institute, and there are now thirteen Affiliated Local Societies in Great Britain, as follows:

Cleveland Institution of Engineers
East Midlands Metallurgical Society
Ebbw Vale Metallurgical Society
Leeds Metallurgical Society
The Lincolnshire Iron and Steel Institute
Liverpool Metallurgical Society
The Manchester Metallurgical Society
The Newport and District Metallurgical Society
North Wales Metallurgical Society
Sheffield Metallurgical Association
Sheffield Society of Engineers and Metallurgists
Staffordshire Iron and Steel Institute
Swansea and District Metallurgical Society.

Arrangements for affiliation remained unchanged and continued to operate to the mutual advantage of the Affiliated Societies and the Institute.

Joint Meetings

In addition to the Joint Meeting with the Sheffield Society of Engineers and Metallurgists and the Sheffield Metallurgical Association and the inaugural meeting of the Powder Metallurgy Joint Group, mentioned earlier in this Report, the Institute participated in two meetings organized by the Ebbw Vale Metallurgical Society, and one by the West of Scotland Iron and Steel Institute, which was held jointly with the Engineers Group.

Metallurgical Societies Overseas

During 1957 the Associação Brasileira de Metais (Brazilian Association for Metals), São Paulo, and the Sociedad Argentina de Metales (Argentine Institute of Metals), Buenos Aires, accepted the Institute's invitations to become "kindred" societies. The number of such societies overseas is now twenty:

American Institute of Mining, Metallurgical, and Petroleum Engineers
American Iron and Steel Institute
American Society for Metals
Associação Brasileira de Metais (Brazil)
Association des Ingénieurs sortis de l'École de Liège (Belgium)
Associazione Italiana di Metallurgia (Italy)
Association Luxembourgeoise des Ingénieurs et Industriels (Luxembourg)
Australian Institute of Metals
Canadian Institute of Mining and Metallurgy
Indian Institute of Metals
Instituto del Hierro y del Acero (Spain)
Jernkontoret (Sweden)
Koninklijk Institut van Ingenieurs (Holland)
Norsk Metallurgisk Selskap (Norway)
Sociedad Argentina de Metales (Argentine)
Société Française de Métallurgie (France)
Société Royale Belge des Ingénieurs et des Industriels (Belgium)
Verein Deutscher Eisenhüttenleute (Germany)
Verein Eisenhütte Oesterreich (Austria)
Verein Schweizerischer Maschinen-Industrieller (Switzerland).

Members of the Institute who are members of, or are on the staff of member firms of, any of the above societies, if resident in the countries concerned, pay reduced membership subscriptions to the Institute. Reciprocal reductions in subscription are granted by a number of the " kindred " Societies to Members of the Institute.

REPRESENTATION AT MEETINGS

Sir Andrew McCance, F.R.S. (Past-President), represented the Institute at the centenary celebrations of the foundation of the Institution of Engineers and Shipbuilders in Scotland, held in Glasgow on 1st May, 1957. Mr. S. Thomson, President of the West of Scotland Iron and Steel Institute and Vice-President of The Iron and Steel Institute, was also present. Mr. K. Headlam-Morley represented the Institute at meetings of the Société Française de Métallurgie in Paris on 7th–12th October, and of the Verein Deutscher Eisenhüttenleute in Düsseldorf on 23rd–26th October. Mr. A. Post represented the Institute at the Second World Metallurgical Congress, organized by the American Society for Metals, in Chicago on 2nd–8th November, 1957.

PRESENTATIONS TO THE INSTITUTE

Imperial Chemical Industries Ltd. made a third gift of twenty guineas to mark their appreciation of the services rendered to them by the Joint Library.

Mr. R. Mather presented a specimen of *Eisenblüte* from the Erzberg, Austria, which had been presented to him during the Institute Meeting in Austria in 1951.

Dr. E. W. Fell presented a copy of a book written by his father, Alfred Fell, in 1908, under the title " The Early Iron Industry of Furness and District."

EDUCATION

Joint Committee for National Certificates in Metallurgy

The Institute was represented on the Joint Committee for National Certificates in Metallurgy by Mr. K. Headlam-Morley.

Sheffield University—Institute Prize, 1957

The Iron and Steel Institute Prize for 1957 at Sheffield University was awarded to Mr. J. K. Wynn.

STAFF

Mr. A. E. Chattin retired on 31st December, 1957, after thirty-two years' service as Assistant Secretary, having reached the age of sixty-five. He was appointed in 1925, and in 1952 also took charge of the Library and Information Department. Mr. Chattin will continue his connection with the Institute on a part-time basis.

Mr. A. Post, who joined the staff in 1946 and became Joint Assistant Secretary in 1952, was appointed Assistant Secretary as from 1st January, 1958.

Mr. M. L. Pearl, who was formerly on the staff of the British Iron and Steel Research Association, joined the staff in November, 1957, and was appointed Librarian and Head of the Information Department as from 1st January, 1958.

The Council again wish to record their appreciation of the services rendered by the staff.

HONOURS CONFERRED UPON MEMBERS

The Council offer their congratulations to all Members who have received honours or appointments during the year. The names have been recorded in the news section of the *Journal*.

FINANCE

The Accounts for 1957 are appended. (Figures for the previous year are printed in brackets for comparison).

GENERAL FUND

Balance Sheet and Income and Expenditure Account

The Balance Sheet at 31st December, 1957, and the Income and Expenditure Account for the year ending on that date, are submitted in the usual form.

Ordinary income at £97,964 (£87,646) exceeded ordinary expenditure, £95,021 (£86,040) by £2943 (£1606); after charging certain special items, the sum of £1801 (£407), excess of income, was transferred to the Accumulated Fund.

Transfers of £1750 were made from the Accumulated Fund to Reserves and the balance, £28,990 (£28,939), was carried to the Balance Sheet. The Life Compositions Fund (£6278, including £210 new compositions), which has hitherto been shown as a separate item in the Balance Sheet, has been transferred to the Accumulated Fund.

A further £1616 has been written off the value of the lease of No. 4 Grosvenor Gardens, London S.W.1. The total amount written off this lease, which runs for 60 years from September, 1955, is £7281 and its value in the Balance Sheet is now £36,697. The total value of the House Fund is £57,160 (£55,950).

TRUST FUNDS

The Accounts of the Andrew Carnegie Research, Williams Prize, Bessemer Medal, and Sir Robert Hadfield Medal Funds are presented as usual. Full use has again been made of the available income.

INVESTMENTS

Most of the stocks in which the funds of the Institute and the Trust Funds are invested have fixed investment values and dates. The investments are valued in the Balance Sheets at what they cost when purchased. In the case of the General (including Life Compositions) and House Funds, the cost was £48,814 (no change) and their market value at 31st December, 1957, was £40,614 (£40,055). In the case of the four Trust Funds, the cost was £38,683* (no change) and their market value at 31st December, 1957, was £32,486 (£34,666).

* This figure includes £474 15*s*. 0*d*. British Transport 3% Guaranteed Stock 1978–1988 at the figure of £400, at which it is included in the Balance Sheet of the Bessemer Medal Fund.

THE IRON AND STEEL INSTITUTE

BALANCE SHEET, 31st DECEMBER, 1957

General Account

1956 £	£	LIABILITIES	£	£
		Accumulated Fund		
28,939		Balance per Account annexed	28,990	
		Add: Transfer from Life Compositions Fund	6,278	35,268
		Current Liabilities and Provisions:		
	14,520	Sundry Creditors (part estimated)	17,041	
	2,619	Due to Life Composition Fund	—	
	1,616	Due to House Fund	852	
	39	Due to Sir Robert Hadfield Medal Fund	44	
	34	Due to Bessemer Medal Fund	42	
	14	Due to Andrew Carnegie Research Fund	—	
	43	Ablett Prize Fund Account	42	
	316	Subscriptions received in advance	252	
	3,596	Payments received in advance for Publications	6,237	
		Sundry Provisions as at 31st December, 1957:		
		Reserve for Comprehensive Index	1,850	
		Transfer from Accumulated Fund	250	
			2,100	
	1,850	*Less* Expenditure during year	700	1,400
		Reserve for Supplementing Staff Pensions	2,500	
	2,500	Transfer from Accumulated Fund	500	
				3,000
				4,400
	—	Bank Overdraft	1,072	
27,147				29,082
£56,086				£65,250

1956 £	£	ASSETS	£	£
		Furniture and Fittings		Not Valued
		Motor Cars at Written Down Value:		1,500
29,953		*Investments at Cost per Schedule* (Market value at 31st December, 1957, £24,438)		29,953
		Current Assets:		
	2,050	Stock of Paper as valued by the Managing Editor	3,523	
	19,070	Sundry Debtors	22,942	
	1,159	Deposits and Payments in Advance	1,433	
	655	Balances at Banks and Cash in hand	466	
22,934				28,364
		Activities in Connection with Publications:		
2,405		Expenditure incurred in advance on Publications		5,372
794		*Special Publications Suspense Account*		61
£56,086				£65,250

Special Funds

1956 £	£		£	£
		Life Composition Fund:		
		Balance at 31st December 1956	6,068	
		Add: Compounded during 1957	210	
			6,278	
		Less Transfer to Accumulated Fund	6,278	
6,068				—
		House Fund:		
		Amount received from Companies	55,950	
		Amount receivable in 1957	750	
			56,700	
		Sundry Creditor	460	
55,950				57,160
£118,104				£122,410

1956 £	£		£	£
6,068		*Life Composition Fund*		—
		House Fund:		
		Lease at Cost less amount written off, per Account annexed	36,697	
		Sundry Debtor	750	
		Investments at Cost, per Schedule (Market Value at 31st December, 1957, £16,176)	18,861	
		Due from General Fund	852	
55,950				57,160
£118,104				£122,410

We have examined the above Balance Sheet of the Institute and found it to be correct.

FINSBURY CIRCUS HOUSE,
BLOMFIELD STREET,
LONDON, E.C.2
19th March, 1958

(*Signed*) W. B. KEEN & Co.,
Chartered Accountants

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST DECEMBER, 1957

EXPENDITURE

1956 £	£		£	£
		Staff Expenses:		
30,780		Salaries and National Insurance	26,348	
2,844		Staff Superannuation Fund and Pension	3,161	
985		Cost of Staff Luncheon Vouchers	1,562	
34,609				41,071
		Other Administrative Expenses:		
2,328		Printing and Stationery	2,331	
1,150		Postage and Receipt Stamps	848	
2,300		Travelling and Entertainment	2,696	
726		Meetings	431	
770		Telephone and Telegrams	946	
224		Insurance	370	
189		Audit Fee—1956	315	
589		Sundry Payments	780	
8,276				8,717
		Establishment Expenses:		
400		Rent	400	
1,438		Rates and Water	1,558	
2,148		Cleaning, Heating and Lighting	2,200	
847		Repairs and Decorations	310	
466		Office Furniture and Fittings	558	
5,299				5,026
		Activities in connection with Publications (excluding Salaries and Overhead Charges):		
31,194		1957 Journal—Printing, Paper, etc.	34,037	
2,885		Other Activities—Expenses	3,012	
—		Adjustments—Amounts under-provided in previous year	209	
34,079				37,258
219		*Translations Service*—Preparation		—
		Library and Information Department:		
781		Library Books and Binding	900	
53		Reviewers' Fees	88	
990		Abstractors' Fees	816	
1,824				1,804
		Miscellaneous:		
1,203		Historical Investigator—Honorarium and Expenses	620	
211		Contributions to Affiliated Local Societies	231	
150		Joint Committee for National Certificates in Metallurgy	180	
10		Prizes	10	
160		Grants	104	
1,734				1,145
86,040				95,021
1,606		Balance carried down		2,943
£87,646				£97,964
—		Cost of Special Entertainment of Overseas Visitors		628
—		Meeting on Air and Water Pollution		842
269		Deficit on Meeting in France		—
459		Special Expenditure on Office Equipment		—
829		Cost of Bessemer Centenary Celebrations		—
407		Excess of Income over Expenditure for the year		1,801
£1,964				£3,271

INCOME

1956 £	£		£	£
		Subscriptions:		
17,355		Current	16,804	
514		Arrears	427	
17,869				17,231
		Payments for Services other than Activities in connection with Publications:		
5,000		British Iron & Steel Research Association	5,000	
150		Andrew Carnegie Research Fund	150	
250		Mond Nickel Fellowship Committee	250	
50		Institute of Metals	—	
—		Co-operative Translation Service	1,000	
5,450				6,400
1,332		*Interest on Investments (gross)*		1,245
1		*Deposit Account*		6
		Institute of Metals:		
842		Rent, Rates and Cleaning	—	
1,000		Library	1,000	
1,842				1,000
775		*Rents Received*		1,566
32		*Sundry Receipts*		5
		Activities in connection with Publications:		
51,634		1957 Journal—Revenue	58,677	
8,373		Other Activities—Revenue	11,834	
22		Adjustments: Amounts over-provided in previous year	—	
60,029				70,511
316		*Translations Service—Sales*		—
£87,646				£97,964
1,606		Balance brought down		2,943
358		Refund of Superannuation Contributions less payments to former members of staff		328
£1,964				£3,271

ACCUMULATED FUND, 31ST DECEMBER, 1957

1956 £	£		£
250		Transfer to Reserve for Comprehensive Index	250
1,000		,, ,, House Fund	1,000
500		,, ,, Reserve for Supplementing Staff Pensions	500
28,939		Balance carried to Balance Sheet	28,990
£30,689			£30,740

1955 £	ASSETS	£
30,115	Balance at 31st December, 1956	28,939
407	Excess of Income over Expenditure for the Year	1,801
157	Joint Metallurgical Societies Meeting in Europe: Net amount recovered	—
10	Premium on Conversion of Defence Bonds	—
£30,689		£30,740

HOUSE FUND—COST OF LEASE ACCOUNT

	£
Lease at Cost including Legal Expenses	43,518
Surveyor's Fees	460
	£43,978

	To 31st Dec., 1956	Current Year	Total
	£	£	£
Transfer from Accumulated Fund	4,000	1,000	5,000
Bank Deposit Interest	121	—	121
Interest on Investments	1,544	616	2,160
	5,665	1,616	7,281
Balance as per Balance Sheet			36,697
			£43,978

ANDREW CARNEGIE RESEARCH FUND

BALANCE SHEET, 31ST DECEMBER, 1957

1956		LIABILITIES		
£	£		£	£
	21,241	*Amount of Original Fund* $100,000	21,241	
	4,596	*Add:* Amount capitalised per last Balance Sheet	4,596	
25,837				25,837
		Sundry Creditors:		
	1,440	Grants	1,590	
	16	Audit Fee	16	
	—	The Iron and Steel Institute—Current Account	161	
1,456				1,767
		Reserve for Travelling Scholarships:		
2,600		Balance at 31st December, 1956		2,600
		Accumulated Fund:		
7,214		Balance per Account annexed		6,406
£37,107				£36,610

1956		ASSETS		
£	£		£	£
34,746		*Investments at Cost as per Schedule* (Market Value 31st December, 1957, £29,261)		34,746
		Balance at Bank:		
	2,161	On Current Account	1,692	
	10	On Deposit Account	10	
	142	Post Office Savings Bank	145	
2,313				1,847
	34	*Sundry Debtor*—Income Tax Receivable		17
	14	*Current Account*—Iron and Steel Institute		—
£37,107				£36,610

ACCUMULATED FUND, 31ST DECEMBER, 1957

£			£	£	
1,450		Grants	2,035	7,322	Balance at 31st December, 1956
150		Contribution to General Fund on account of Salaries	150		Income for the year ended 31st December, 1957:
16		Audit Fee	16	1,483	Interest on Investments (gross)
—		Medal	4	8	Interest on Deposits
7,214		Balance carried forward	6,406	1,491	
				17	Premiums on Conversion and Profit on Redemption of Defence Bonds
£8,830			£8,611	£8,830	

£	£
	7,214
1,393	
4	
	1,397
	—
	£8,611

WILLIAMS PRIZE FUND

BALANCE SHEET, 31ST DECEMBER, 1957

1956	LIABILITIES		
£		£	£
2,220	*Capital Value* representing Market Value of £3,000 3¼% Conversion Loan on 21st September, 1926 when the Fund was inaugurated	2,220	
587	Accumulated Fund—Balance per Account annexed	561	
£2,807		£2,781	£2,807

1956	ASSETS		
£		£	£
2,769	*Investments at Cost per Schedule* (Market Value at 31st December, 1957—£2,275)		2,769
	Balance at Bank:		
38	On Current Account		12
£2,807			£2,781

ACCUMULATED FUND, 31ST DECEMBER, 1957

£			£	£	
—	200	Awards	150	662	Balance 31st December, 1956
587		Balance carried forward	561		Income for the year ended 31st December, 1957:
				121	Interest on 3¼% Conversion Loan
				3	Interest on Defence Bonds
				1	Interest on Post Office Savings Bank Account
				125	
£787			£711	£787	

£	£
	587
121	
3	
—	
	124
	£711

BESSEMER MEDAL FUND

BALANCE SHEET, 31st DECEMBER, 1957

1956	LIABILITIES	£	£	1956	ASSETS	£	£
£				£			
	Capital Value representing Market Value of £400 4% Debenture of the L. & N.W. Railway	400			*Investments:* £474 15*s.* 0*d.* British Transport 3% Guaranteed Stock 1978/88	400	
900	*Grant* from the Iron and Steel Institute	500		900	£500 4% Funding Stock 1960/90	500	
			900		(Market Value 31st December 1957, £723)		900
34	*Accumulated Fund*—Balance per annexed Account		42	34	*Sundry Debtor:* The Iron and Steel Institute		42
£934			£942	£934			£942

ACCUMULATED FUND, 31st DECEMBER, 1957

£		£	£		£	£
26	Medal	26	26	Balance 31st December, 1956		34
34	Balance carried forward	42		*Income for year ended 31st December, 1957:*		
				Interest on British Transport Stock	14	
			34	Interest on 4% Funding Stock	20	
						34
£60		£68	£60			£68

SIR ROBERT HADFIELD MEDAL FUND

BALANCE SHEET, 31st DECEMBER, 1957

1956	LIABILITIES	£	1956	ASSETS	£
£			£		
268	*Capital Value* representing Market Value of £267 11*s.* 2*d.* 3% Savings Bonds 1955/65	268	268	£267 11*s.* 2*d.* 3% *Savings Bonds* 1955/65 (Market Value at 31st December, 1957 £227)	268
39	Accumulated Fund—Balance per Account annexed	44	39	*Sundry Debtor*—The Iron and Steel Institute	44
£307		£312	£307		£312

ACCUMULATED FUND, 31st DECEMBER, 1957

£		£	£		£
4	Medal	3	35	Balance 31st December, 1956	39
39	Balance carried forward	44		Income for year ended 31st December, 1957:	
			8	Interest on 3% Savings Bonds	8
£43		£47	£43		£47

THE IRON AND STEEL INSTITUTE

SCHEDULE OF INVESTMENTS AT 31ST DECEMBER, 1957

SHOWING NOMINAL VALUES, COST, AND PRESENT MARKET VALUES

GENERAL FUNDS OF THE INSTITUTE

Nominal Value	Nature of Security	Market Value, 31st December, 1957	Cost Value
£ s. d.		£	£
2,197 7 0	3½% War Stock	1,384	2,161
1,324 7 4	3½% Conversion Loan	835	1,254
2,954 1 0	4% Consolidated Stock	2,058	3,176
10,042 19 3	4% Funding Loan 1960/90	8,687	7,483
2,000 0 0	3% Savings Bonds 1955/65	1,700	2,000
5,000 0 0	do. 1955/65	4,250	4,972
2,000 0 0	do. 1960/70	1,510	2,000
1,500 0 0	do. 1965/75	1,058	1,500
4,854 2 0	British Transport 3% Guaranteed Stock 1978/88	2,961	5,407
		£24,438	£29,953

HOUSE FUND

10,000 0 0	4% Funding Stock 1960/90	8,650	10,131
3,200 0 0	do.	2,768	3,251
2,200 0 0	do.	1,903	2,030
681 13 0	do.	590	600
196 10 1	do.	170	231
587 13 10	3½% Conversion Loan	370	513
205 15 6	3½% War Stock	130	212
2,615 11 2	British Transport 3% Guaranteed Stock 1978/88	1,595	1,893
		£16,176	£18,861

ANDREW CARNEGIE RESEARCH FUND

(Trustees: Sir William Larke, K.B.E., The Hon. R. G. Lyttelton, and N. H. Rollason)

6,897 14 11	3½% War Stock	4346	6,896
800 0 0	do.	504	794
2,693 12 0	3½% Conversion Loan	1,697	2,007
3,922 14 10	4% Conversion Stock 1957/58	3,903	3,998
1,793 15 0	British Electricity 3% Guaranteed Stock 1968/73	1,292	1,762
4,166 18 7	4% Funding Stock 1960/90	3,604	4,676
500 0 0	4½% Defence Bonds (Conversion Issue)	500	500
17,812 10 3	British Transport 3% Guaranteed Stock 1978/88	10,866	10,863
1,000 0 0	3% Savings Bonds 1955/65	850	1,000
2,250 0 0	do. 1960/70	1,699	2,250
		£29,261	£34,746

WILLIAMS PRIZE FUND

(Trustees: Sir William Larke, K.B.E., The Hon. R. G. Lyttelton, and N. H. Rollason)

3,452 15 7	3½% Conversion Loan	2,175	2,670
100 0 0	3½% Defence Bond (Conversion Issue)	100	99
		£2,275	£2,769

SIR ROBERT HADFIELD MEDAL FUND

267 11 2	3% Savings Bonds 1955/65	227	268

BESSEMER MEDAL FUND

(Trustees; Desmond Lysaght, The Hon. R. G. Lyttelton, and N. H. Rollason)

474 15 0	British Transport 3% Guaranteed Stock 1978/88	290	—
500 0 0	4% Funding Stock 1960/90	433	500
		£723	£500

(*Signed*) W. BARR,
Hon. Treasurer

(*Signed*) K. HEADLAM-MORLEY,
Secretary

We have examined the foregoing Balance Sheets and Income and Expenditure Accounts with the Books and Vouchers of the Institute and certify them to be correct. We have also verified the balances at the Bankers and the Securities for the Investments shown above.

FINSBURY CIRCUS HOUSE
BLOOMFIELD STREET, E.C.2
19th March, 1958

(*Signed*) W. B. KEEN & CO.,
Chartered Accountants

PROGRAMME OF SPECIAL MEETING IN BELGIUM AND LUXEMBOURG, 1958

THE COUNCIL have accepted an invitation from the Presidents of the Centre National de Recherches Métallurgiques, the Groupement des Industries Sidérurgiques Luxembourgeoises, and the Groupement des Hauts Fourneaux et Aciéries Belges to hold a Special Meeting of the Institute in Belgium and Luxembourg from **17th to 28th June, 1958,** at the same time as the Journées Internationales de Sidérurgie, 1958, which are being organized in Belgium and Luxembourg on the occasion of the Brussels World Exhibition.

H.M. The King of the Belgians and H.R.H. The Grand Duchess of Luxembourg have graciously consented to become Patrons of the Meetings; in addition, the Meetings will be held under the patronage of the Belgian and Luxembourg Governments.

The Meeting is divided into three sections—SECTION I from 17th to 21st June in Liège; SECTION II from 21st to 25th June in Luxembourg; and SECTION III from 25th to 28th June in Brussels and Charleroi. The detailed programme is given below.

SECTION I—LIÈGE

Tuesday, 17th June

Evening
Members and ladies arrive in Liège.

Wednesday, 18th June

Morning
Members and ladies—Inaugural Session and technical meeting in the Palais des Congrès (1st Session).
Afternoon
Members—Technical meeting in the Palais des Congrès (2nd Session).
Ladies—Excursion A: Tour of Liège.
Evening
Members and ladies—Dinner at Spa by invitation of the Centre National de Recherches Métallurgiques (dress: dinner jacket).

Thursday, 19th June

Morning
Members—Technical meeting in the Palais des Congrès (3rd Session).
Afternoon
Members—Either technical meeting in the Palais des Congrès (4th Session) or visit to *one* of the following works:
Excursion 1—S.A. Cockerill-Ougrée, Seraing (blast-furnaces and pilot low-shaft furnace).
Excursion 2—Research laboratories of the Centre National de Recherches Métallurgiques, Liège.
Excursion 3—S.A. des Usines à Tubes de la Meuse, Flémalle (seamless and large-diameter welded tube mills).
All day
Ladies—Free.
Evening
Members and ladies—Reception: Supper and dance at the Palais des Congrès, by invitation of the Mayor of Liège (dress: dinner jacket).

Friday, 20th June

Morning
Members—Visit to *one* of the following works:
Excursion 4—S.A. Métallurgique d'Espérance-Longdoz (blast-furnaces and steelworks).
Excursion 5—S.A. Cockerill-Ougrée (rolling mills for heavy plates, sheets, and sections).
Excursion 6—S.A. Cockerill-Ougrée, Ferblatil Division (cold continuous strip mills, tinning lines).
Afternoon
Members—Visit to *one* of the following works:
Excursion 7—S.A. Métallurgique d'Espérance-Longdoz (hot and cold strip and sheet mills).
Excursion 8—S.A. Cockerill-Ougrée (blast-furnace, open-hearth and Bessemer steelworks).
Excursion 9—S.A. Phénix Works (sheet mills).
All day
Ladies—Excursion B—Motor bus tour in the Belgian Ardennes, with lunch and tea.
Evening
Members and ladies—Evening free.

Saturday, 21st June

Morning
Members—Visit to *one* of the following works:
Excursion 10—S.A. Métallurgique d'Espérance-Longdoz (same as Excursion 4).
Excursion 11—S.A. Cockerill-Ougrée, Ferblatil Division (same as Excursion 6).
Excursion 12—S.A. des Usines à Tubes de la Meuse (same as Excursion 3).
Ladies—Free.
Afternoon
Members and ladies—Travel by special train from Liège to Luxembourg.

SECTION II—LUXEMBOURG

Saturday, 21st June

Evening
Members and Ladies—Arrive in Luxembourg; thereafter free.

A VIEW of the Upper Works at Coalbrook Dale in the County of SALOP. Designed and Published by G. Perry and T. Smith 1758 according to Act of Parliament.

[To face p. 12

An Early Engraving of Coalbrookdale

The picture overleaf is an engraving after drawings by Thomas Smith of Derby and George Perry, an engineer at Coalbrookdale. It shows the Upper Works at Coalbrookdale, Shropshire, with the furnace known as the " Old Furnace " in the centre; the square top, from which flames and smoke are rising, can just be seen. The furnace pool can be seen to the right of the works, and across the pool on a hill are the house of Abraham Darby II and the Friends' Meeting House. On the road in the foreground a large engine cylinder is being transported on a waggon drawn by six horses. On the right, between the road and the pool, there are four heaps of smoking coal being converted into coke. The employment of coke instead of charcoal, up to then the only fuel for iron smelting, was first achieved by Abraham Darby I (1678-1717) at the " Old Furnace " of Coalbrookdale, shown in the picture, in 1709. It laid the foundation of the modern iron industry.

The engraving from which the picture overleaf was taken belongs to Major Cuthbert Johnson, M.B.E., M.A.; it came to him through his maternal grandfather, Joseph Coventry, of Sefton Park, Liverpool, who had a considerable interest in Coalbrookdale during the period 1870–1890. Major Johnson has kindly loaned the engraving to the Institute, and it can be seen at 4 Grosvenor Gardens.

Sunday, 22nd June

All day

Members and ladies—Excursion C: Motor bus excursion to "Petite Suisse Luxembourgeoise," with lunch en route.

Evening

Members and ladies—Free.

Monday, 23rd June

Morning

Members and ladies—Inaugural Session and technical meeting (Session 5) in the Palais des Expositions.

Afternoon

Members—Technical meeting (Session 6) in the Palais des Expositions.

Ladies—Excursion D: Tour of Luxembourg city.

Evening

Members and ladies—Free.

Tuesday, 24th June

Morning

Members—Either technical meeting (Session 7) in the the Palais des Expositions, *or* visit to *one* of the following works:

Excursion 13—ARBED-Terre Rouge (ore preparation and agglomeration plant), and ARBED-Belval (continuous narrow strip mills).

Excursion 14—ARBED-Dudelange (hot and cold sheet mills).

Afternoon

Members—Either technical meeting (Session 8) in the Palais des Expositions, *or* visit to *one* of the following works:

Excursion 15—ARBED-Esch (blast-furnace and Bessemer steelworks, including desulphurization practice).

Excursion 16—HADIR-Differdange (steelworks with 50-ton converters; heavy section mills and sheet piling; medium continuous strip mills; electric-welded tubes.)

All day

Ladies—Free.

Evening

Members and ladies—Reception and dinner at the Palais des Expositions, by invitation of the Groupment des Industries Sidérurgiques Luxembourgeoises (dress: dinner jacket).

Wednesday, 25th June

Morning

Members—Visit to *one* of the following works:

Excursion 17—ARBED-Terre Rouge and ARBED-Belval (same as Excursion 13).

Excursion 18—ARBED-Dudelange (same as Excursion 14).

Excursion 19—HADIR-Differdange (same as Excursion 16).

Excursion 20—S.A. Minière et Métallurgique de Rodange (Bessemer steelworks and continuous rod and bar mills).

Ladies—Free.

Midday

Members and ladies—Reception and luncheon, by invitation of the High Authority of the European Coal and Steel Community.

Afternoon

Members and ladies—Leave by special train for Brussels.

SECTION III—
BRUSSELS AND CHARLEROI

Wednesday, 25th June

Evening

Members and ladies—Arrive in Brussels.

Thursday, 26th June

Morning

Members—Visit to *one* of the following works near Charleroi:

Excursion 21—S.A. des Forges de la Providence, Marchienne-au-Pont (blast-furnace burden preparation plant).

Excursion 22—S.A. des Aciéries et Minières de la Sambre (Bessemer steelworks with oxygen and carbon dioxide blowing).

Excursion 23—S.A. des Hauts Fourneaux, Forges et Aciéries de Thy-le-Château et Marcinelle (semi-continuous billet mill); and laboratories of the Centre National de Recherches Métallurgiques, Hainaut.

Afternoon

Members—Visit to *one* of the following works:

Excursion 24—S.A. des Forges de Clabecq (electric steelworks; wire-rod mills).

Excursion 25—Continuous casting plant of the Centre National de Recherches Métallurgiques, located at the works of S.A. des Aciéries et Minières de la Sambre.

All day

Ladies—Free in Brussels.

Evening

Members and ladies—Free in Brussels.

Friday, 27th June

Morning

Members—Technical meeting at the Palais des Beaux Arts, Charleroi (9th Session).

Afternoon

Members—Technical meeting at the Palais des Beaux Arts, Charleroi (10th Session).

All day

Ladies—Free in Brussels.

Evening

Members and ladies—Dinner in the Palais des Beaux Arts, Charleroi, by invitation of the Centre National de Recherches Métallurgiques, Hainaut (dress: lounge suit).

Saturday, 28th June

Morning

Members and ladies—Closing session in the Salle des Galeries Louise, Brussels.

Midday

Members and ladies—Luncheon in the Palais de l'Elégance at the Exhibition, by invitation of the Groupement des Hauts Fourneaux et Aciéries Belges.

END OF THE MEETING

TECHNICAL MEETINGS

Joint technical meetings of The Iron and Steel Institute and the Journées Internationales de Sidérurgie will be held at Liège, Luxembourg, and Charleroi. The proceedings will be conducted in English, French, and German, with simultaneous translation facilities available between these three languages.

Preprints of all the papers to be presented at each session will be distributed in advance to those attending. The papers will be printed in their language of origin with a synopsis of each paper in English, French, and German.

All the papers to be presented in Liège and Charleroi will be published in due course in their language of origin in the *Revue Universelle des Mines*. All papers to be presented in Luxembourg will be published in due course, in their language of origin, in the *Revue Technique Luxembourgeoise*. Some of the papers will also be published in English in the *Journal* (these are marked * in the list below): synopses in English of all the papers to be presented at the meetings will be published in the June *Journal*.

The following is a list of the papers to be presented at each session.

LIÈGE—"NEW DEVELOPMENTS IN STEELMAKING"

1st Session—Converter Processes

Morning, Wednesday, 18th June

1. "General Review of Pneumatic Processes," by J. Daubersy (Centre National de Recherches Métallurgiques, Liège—Belgium).
2. "Use of Low-phosphorus Iron in Bottom-blown Basic Converters," by H. Kosmider, A. Weyel, and H. Neuhaus (Klockner-Hüttenwerke Haspe, A.G.—Germany).
3. "The 'Phoenix–Lanzen' Process," by Dr. Ing. H. T. Brandi (Phoenix-Rheinrohr A.G.—Germany).
4. "French Experience with Bottom-blown Converters," by M. Allard (Institut de Recherches de la Sidérurgie—France).
5. "Refining Pig Iron with Oxygen by the Kaldo Process," by Prof. Bo Kalling (Stora Kopparbergs Bergslags A.B.—Sweden).
6. "The Rotor Process," by Dr. Ing. R. Graef and Dipl. Ing. L. V. Bogdandy (Hüttenwerk Oberhausen, A.G.—Germany).

2nd Session—Converter Processes (contd.)

Afternoon, Wednesday, 18th June

1. "The Treatment of Iron Containing 0·5–1·5% Phosphorus by the L.D. Process," by Dipl. Ing. H. Trenkler (Vereinigte Oesterreichische Eisen und Stahlwerke, A.G.—Austria).
2. "The Manufacture of Special Steels by the L.D. Process," by Dipl. Ing. O. Cuscoleca and Dipl. Ing. H. Rosner (Oesterreichisch Alpine Montangesellschaft—Austria).
3. "A New Refining Process for Pig Iron using Pure Oxygen and Lime Powder," by B. Trentini and M. Allard (Institut de Recherches de la Sidérurgie—France).
4. "Recent Developments in the Refining of Pig-Iron with Pure Oxygen," by M. P. Metz (ARBED–Dudelange—Luxembourg).

3rd Session—Open-hearth Furnace Practice

Morning, Thursday, 19th June

1.* "The Driving Rate of Open-Hearth Furnaces." by R. W. Evans (Steel Company of Wales Ltd.), J. Allen (Consett Iron Co. Ltd.), Dr. J. H. Chesters (United Steel Companies Ltd.), Dr. A. J. Kesterton (Steel Company of Wales Ltd.) and Dr. J. Pearson (British Iron and Steel Research Association—Great Britain).
2.* "Basic Open-hearth Steelmaking in the U.S.A., by M. W. Lightner and D. L. McBride (United States Steel Corporation—U.S.A.).

4th Session—Large Electric Furnace Practice

Afternoon, Thursday, 19th June

1. "Results Obtained with a 150-ton Electric Furnace," by G. Stassin (Fabrique de Fer de Charleroi—Belgium).
2. "Large Electric-arc Furnace Steelmaking Experience in the U.S.A.," by A. C. Ogan and D. J. Carney (United States Steel Corporation—U.S.A.).

LUXEMBOURG—"NEW DEVELOPMENTS IN IRONMAKING"

5th Session—The Low Shaft Furnace

Morning, Monday, 23rd June

"The Low Shaft Furnace—Experience and Results," by H. Malcor (Institut de Recherches de la Sidérurgie—France).

6th Session—New Direct Reduction Processes

Afternoon, Monday, 23rd June

1. "Direct Reduction Processes for Iron Ore," by P. E. Cavanagh (Ontario Research Foundation—Canada).
2. "Developments in Europe," by Prof. A. Scortecci (Instituto Siderurgico FINSIDER—Italy).

7th Session—Recent Developments in Blast-furnace Practice

Morning, Tuesday, 24th June

1.* "Survey of Modern Blast-furnace Techniques," by Dr. T. P. Colclough, C.B.E. (British Iron and Steel Federation—Great Britain).
2. "Use of Oxygen, Moisture, and High Top Pressure in Blast-furnace Operation," by J. M. Strassburger (National Steel Co.—U.S.A.).

8th Session—Preparation of Blast-furnace Burden

Afternoon, Tuesday, 24th June

1. "Experience in Luxembourg," by J. Paquet (ARBED–Belval—Luxembourg).
2. "French Experience," by J. Astier (Institut de Recherches de la Sidérurgie—France).
3.* "A Programme-Controlled Reduction Test for Blast-furnace Burdens," by R. Linder (Oxelösunds Järnverks A.B.—Sweden).
4.* "Experience with Sinter Burden in Swedish Blast-furnaces," by U. Notini (Jernkontoret—Sweden).

CHARLEROI—"CONTINUOUS CASTING OF STEEL"

9th Session—Theoretical Considerations and Experimental Equipment

Morning, Friday, 27th June

1. "General Review," by J. Gouzou (Centre National de Recherches Métallurgiques, Hainaut—Belgium).
2. "Description of Results obtained at Centre National de Recherches Métallurgiques, Hainaut," by M. Zaeytydt (C.N.R.M.—Belgium).
3.* "Continuous Casting on the B.I.S.R.A. Experimental Plant," by G. Fenton and Dr. J. Pearson (British Iron and Steel Research Association—Great Britain).
4. "The Control of the Flow of Liquid Metal during Continuous Casting," by Dr. W. Siegfried (Battelle Memorial Institute, Geneva—Switzerland).

10th Session—Industrial Applications of Continuous Casting

Afternoon, Friday, 27th June

1. "Some Features of Continuous Casting at Barrow," by I. M. D. Halliday (Barrow Steel Works Ltd.—Great Britain).
2. "Experience in Germany," by Dr. G. Speith (Mannesmann-Hüttenwerke, A.G.—Germany).
3. "Recent Experience in the Continuous Casting of Steel," by Dr. H. Krainer and B. Tarman (Gebr. Böhler, A. G.—Austria).
4. "Continuous Casting of Steel in France," by P. Thomas (Soc. des Hauts Fourneaux et Forges d'Allevard—France).
5.* "Canadian Experience," by G. C. Olson (Atlas Steels Ltd.—Canada).

POWDER METALLURGY JOINT GROUP

The Iron and Steel Institute · The Institute of Metals

Recent Developments in Powder Metallurgy

By I. Jenkins, D.Sc., F.I.M.

AN INAUGURAL LECTURE to a newly constituted scientific and technology group would seem to have the advantage that being the first one the lecturer has unlimited scope from which to draw his material. However, after accepting the invitation of your Committee to talk to you to-day on developments in powder metallurgy since the last British symposium on this subject, I have realized that there are various factors which make this task not quite as straightforward as would at first appear. The last British Symposium on Powder Metallurgy was held under the auspices of our two Institutes almost exactly three years ago. Since then, there have been meetings of a similar nature in Austria, Italy, Eastern and Western Germany, and sundry meetings in the United States sponsored by the American metallurgical societies and the Powder Metallurgy Association there. There has also appeared a large and comprehensive report of an O.E.E.C. Mission to the United States on the powder metallurgy industry in that country. Those of you who are directly associated with the industry will already be familiar with the recorded proceedings of these various meetings and would not wish to hear from me to-day a catalogue of what would be already well known facts. Neither would I wish to anticipate in any detail the papers which we are to hear later on to-day and at our meeting in March next which will review developments in the fields of powder manufacture, compaction, and sintering. It seemed to me, therefore, that my best compromise was to confine myself to a few general observations on the progress of the industry and to express some personal thoughts on certain scientific aspects of this subject.

The extent to which we may consider that the industry has progressed in the past three years will depend upon whether we consider the volume of production, the range of materials made, improvements mainly in the engineering aspects of the manufacturing processes, or the strengthening of the scientific principles on which the manufacturing processes are based. Taking a detached look at the indsutry from each of these viewpoints, I very much doubt whether the extent of the progress made in Great Britain during the past three years can be wholly satisfying to those directly concerned with the well-being of the industry.

True, the volume of production of sintered parts has increased fairly steadily since 1954 and there has been an increase in the number of manufacturers in this country, particularly of sintered iron and steel. There are no direct statistics available covering this period, but I understand that in 1955, for example, the sale of sponge and electrolytic iron powders, used for powder metallurgical purposes, increased by 50% over the 1954 figure, whilst it is expected that the current year will show a further 50% increase over the 1955 value, giving an estimated figure of about 1200 tons. However, part of these increases, no doubt, has been at the expense of other sources of powder; furthermore, during the corresponding period there has been a general increase in the consumer demand for engineering materials as a whole, and it is doubtful whether the overall increase in the consumption of powder represents a significant expansion of the industry into new fields of application. I would expect that the same can be said for most of the other products of the industry in this country, although the demand for wrought tungsten and molybdenum has increased significantly. No doubt, commercial and economic reasons can be given to account for this little progress, but this is a technical meeting and the point we should note, I feel, is that there has been no major technical development in this period to stimulate a greater volume of production.

Introductory Lecture given at the Inaugural Meeting of the Powder Metallurgy Joint Group on 4th December, 1957.

Dr. Jenkins is Chief Metallurgist at the Research Laboratories of the General Electric Company Ltd.

MATERIALS

The range of materials made by powder metallurgy to-day presents very much the same pattern as was evident in 1954. Bronze and iron may have changed places for certain applications, as also may some of the hard metals, whilst the newer compounds such as borides and silicides are only now beginning to appear, almost reluctantly it would seem, on the production scene. Certain of the interesting development work described at the 1954 meeting, in connection with alloys and cermets for high temperature applications and the dispersion-hardened light metals, has yet to lead to new sintered products, in spite of continued technical effort to this end. In the intervening years, also, atomic energy and the British nuclear power programme has made its impact on the metal-making and engineering industries in this country but has had little impact, as yet, on powder metallurgy. The increasing amount of declassified information now coming out from the Atomic Energy Authority, however, indicates that powder metallurgy may play a significant role in the development of advanced reactors. Processes have been developed satisfactorily for the production of uranium powder, either by direct reduction of uranium dioxide by calcium, or by decomposition of the hydride which is produced from the metal in bulk, but the manufacturing process which has been adopted is that of vacuum melting. The major use of the powder is likely to be in the manufacture of enriched fuel elements where the high material yield of the process is of advantage, since the materials used are scarce and expensive. Alternatively, the powder may be used for the preparation of interstitial and intermetallic compounds, such as uranium carbide, silicide, and beryllide which, if necessary, can be incorporated in metallic matrices by powder metallurgy methods to give cermet-type fuel elements having particular advantages such as stability under irradiation conditions and improved thermal transfer because of the metallic matrices.

Thorium metal powder is now produced by calcium reduction of thoria and here, in view of the high melting point of the metal, powder metallurgy methods offer a real advantage compared with vacuum melting.

Still in the field of atomic energy, powder metallurgy is being employed to develop materials such as beryllium, niobium, and vanadium which are of potential value as sheathing materials in reactors. Earlier this year The Institute of Metals held a symposium on niobium which included descriptions of the powder metallurgy method employed for the manufacture of this metal, and this, no doubt, will be familiar to most of you.

Because of the large grain size and unsatisfactory mechanical properties of cast beryllium, powder metallurgy is being used in an attempt to produce a satisfactory fuel element sheathed in this material. Integral sheathing methods, such as coextrusion, are being developed and offer some promise.

In the case of the development of most of these newer metals, of course, the chemical engineering work associated with the preparation of the metal powders has been of considerable merit, and we shall be hearing more of this aspect later on to-day.

PROCESSES

Turning now to developments in the manufacturing processes themselves, we shall be discussing later to-day developments in the manufacture and quality of metal powders. I will anticipate this only to the extent of commenting that perhaps one of the most interesting developments in powder production since 1954 has been that of atomized alloy powders. Whilst the atomizing process itself is by no means new, it is now possible to produce, by this method, powders of high-temperature alloys and alloy steels which have excellent sintering characteristics and which, in certain cases, yield sintered products having both room and high-temperature mechanical properties as good as those of the equivalent alloy in the wrought state. This is particularly so in the case of high-temperature and stainless alloys, and tensile strengths of 50 tons/in^2 are claimed for an age-hardening austenitic steel in the as-sintered state.

During the last year or two, also, double pressing and high-temperature sintering of ferrous and non-ferrous parts have come to be considered as standard methods of production, with the associated improvements in strength and ductility which are so desirable. Whether or not improvements in the control and quality of pre-alloyed powders will eliminate these double treatments altogether remains to be seen.

One of the interesting developments reported in the 1954 symposium was that of the compaction of metal powder by rolling. To the best of my knowledge this process has not yet been developed on a production basis, but this stage has almost been reached with certain metals and alloys. We can expect to hear more of this interesting development at the March meeting.

Slip-casting forming techniques have been used in the ceramic industries for many years for the manufacture of hollow ware and intricate shapes. Its possible application to the formation of metallic components from metal powders has been suggested in the past, apparently without success, but within the last couple of years a systematic approach has been made to this process as a powder metallurgy technique, more particularly in the U.S.A. The basis of the process is to prepare a slurry of the metal powder with a suitable liquid, the composition of which is important and to cast this into a plaster of paris mould of the form required when the liquid content of the slurry is absorbed by the plaster leaving the powder behind to take up the form of the mould. The metal component is then stripped from the mould and sintered. Whilst this manufacturing technique could be useful and complementary to those already existing, particularly for the production of a limited number of complex components, perhaps the particular significance of the technique is the claim made in regard to the mechanical properties which can be achieved in metals and alloys produced in this way. For example, stainless-steel components having a density of 7·15 g/cm^3 are stated to have an ultimate tensile strength of over 28 tons/in^2 and an elongation of more than 22%. Normally these properties are obtained only by re-pressing and re-sintering.

On the manufacturing equipment side, developments in powder mixing and grinding, and in automatic and semi-automatic presses, have not yielded anything spectacular, although, on the Continent, sintered molybdenum blocks weighing up to 2 cwt can now be produced. In the field of sintering, furnaces are now available in this country for continuous sintering in a controlled atmosphere at temperatures in excess of 1200°C. Vacuum sintering has been receiving increasing attention not only in relation to metals which demand a vacuum by virtue of their composition, but also for certain carbides and engineering alloys which in the past have been sintered in a controlled atmosphere. It is claimed that vacuum sintering in certain cases yields a product having improved mechanical properties, both as regards strength and ductility. Obviously, the process is limited to those metals and alloys which have an insignificant vapour pressure at the sintering temperature involved.

RESEARCH

When we turn to the fourth category of assessing progress—that of the strengthening of the principles on which the manufacturing processes are based—we do not appear to have advanced very far in recent years. True, there have been a number of publications on sintering phenomena, on bonding in interstitial compounds, and equilibrium diagram studies relating to carbides, silicides, and borides, etc. There has also been a considerable amount of commendable technological work in most branches of the industry, leading to the developments already described in atomization and the use of pre-alloyed powders, in compaction techniques, in vacuum and high-temperature sintering, etc., all of which are stimulating to the industry as a whole. Such exploratory work, although mainly of an engineering character, may produce those new and spectacular developments which any industry must receive from time to time if it is to be progressive and competitive. I venture to suggest, however, that this will not be realized unless there is a corresponding effort on fundamental metallurgical work aimed at solving practical problems and at strengthening our understanding of the behaviour of the materials involved both during and after manufacture. In recent years there has been very little effort of this kind provided by the industry, either at home or abroad. The need for this is greater now than ever before, if only because of the increasing competition which the powder-metallurgy process will continue to receive from other metal manufacturing processes such as drop forging, die casting, arc and vacuum melting, etc. It is no longer true that certain metals and alloys are the exclusive prerogative of powder metallurgy either by virtue of a high melting point, chemical activity, or because of the peculiar properties which the powder-metallurgy manufacturing process confers upon them.

In encouraging a more scientific approach to the basic problems associated with powder metallurgy, the industry can, as indeed can any other industry, approach the matter either by undertaking the fundamental work itself and/or by applying fundamental work done elsewhere to its own needs. Let us consider certain of the problems in powder metallurgy for a moment from these points of view.

Sintering

Work has been proceeding for many years aimed at establishing a better understanding of the sintering mechanism, but whether or not a pore closes by virtue of volume diffusion, or surface, or grain-boundary diffusion is still a matter for debate. When certain wrought materials are stressed below their yield point, cavitation may be produced due to grain-boundary sliding. Here then is a means for producing, artificially, small pores in materials and for studying what happens to them when the stress is removed and the process, so to speak, is put in reverse. Would such a pore gradually close up once again and begin to round off at the points where the grain boundaries meet it, indicating that under these circumstances the primary mechanism for pore closure is surface diffusion along the grain boundary? Recent work in the United States suggests that this may be so. Certain materials when stressed will also develop small pores along a grain boundary. Measurements of self diffusion have indicated that the rate at which these pores develop cannot be accounted for by the self diffusion of the metal atoms through the crystals and can be accounted for only by the greater rate at which atoms will diffuse along grain boundaries. It would seem that work of this kind might help considerably in obtaining a better understanding of what is the dominating mechanism in the sintering of pure metal powders.

But where, you might ask, is work of this kind likely to have practical significance? At the 1954 symposium, we were told of the beneficial effect which small traces of chemically active materials can have on the development of mechanical properties in sintered materials. The process which was given the name of ' activated sintering ' is now being used in the manufacture of a number of sintered products, where elements, such as the halogens and boron, are used to improve the mechanical properties of sintered materials, particularly in respect of ductility. An explanation of the effect of the activating agent was tentatively proposed at the 1954 symposium, but I am not aware of any work which has been done since which has established conclusively precisely what goes on under these circumstances. It is surprising that this important development, in view of its success, has not been investigated more basically. To suggest that the agents function by activating the metal surface or by removing impurities is mere speculation, and, until we learn more about the fundamental mechanism which is going on, the more empirically will it be employed and the less opportunity will there be for it to be used to maximum advantage. Basic studies on the properties of metallic surfaces, including those created by grain-boundary movement and internal fracture in wrought materials, could be of value in the development of sintering processes as such.

Grain Boundaries

We know very little indeed about the role of impurity atoms, either in solution in metals or as films on metal particles, on the mechanism of sintering and on the properties, particularly mechanical, of the sintered product. A considerable amount of fundamental work is now going on on the nature of deformation and fracture in metals, and the associated effects of impurities. The fracture of sintered materials, unless they have been subsequently worked and re-sintered, is almost invariably intergranular. To say that this is due to the segregation of impurity atoms and impurity particles at grain boundaries is merely begging the question. It does not necessarily follow that all types of impurity atom and impurity particle should cause weakness at a grain boundary. This depends very much upon the nature and the distribution of the impurities and, in the case of precipitates, whether they are coherent or not with the surrounding metal matrix. Recent work on fracture of wrought materials has shown that grain-boundary porosity resulting from stressing does not necessarily induce rapid grain-boundary fracture, neither does the presence of insoluble particles *per se* necessarily give rise to the same effect. In certain cases, a grain boundary may be strengthened by an insoluble particle of one type, but weakened by the presence of one of different chemical composition. Precisely why one type of particle should give rise to weakness and another not, is not understood but it is probably associated with the nature of the interface between the particle and the surrounding metal. If this interface has a high energy then the progress of a crack through the interface is not as rapid as in the case of a weak bond of lower energy. The importance of work of this kind in relation to the mechanical properties of sintered materials will be obvious, in view of the advantage which the powder-metallurgy process may have in being able to produce metals with controlled precipitates at the grain boundaries. There is a great deal of work that can be done here of a fundamental character which undoubtedly will be of considerable practical importance if it leads to a better understanding of the role of impurity atoms

and precipitates at grain boundaries in sintered materials.

Hard Metals

As I mentioned earlier, a considerable amount of work is still going on aimed at a better understanding of the nature of bonding in certain interstitial compounds, particularly borides and silicides. Their sister materials, the carbides and the cemented carbides, have been with us for a very long time and certain it is that during the past 25 years we have learnt a very great deal about carbides and mixed carbide systems. Whilst recognizing that the nature of the bonding in hard metals is extremely complex, it is true to say that we know very little about it and what the relationship is between it and the mechanical and physical properties of the carbide, either in the pure or in the cemented state. Probably many of you will have seen the recent publication by Dr. Pol Duwez in which he establishes a case for a programme of fundamental research on hard metals, and it is only necessary for me to underline certain of the points which he makes in this excellent summary of the situation. With the improved laboratory techniques now available for preparing materials in a very high state of purity, the time is certainly ripe to examine very pure interstitial compounds such as carbides, borides, and silicides, in the form both of polycrystalline and single-crystal specimens. Basic studies in such systems, using the modern metallurgical facilities which are now available in most laboratories, should help us to understand better the nature of the bonding mechanism in the compounds, the nature of the defects in their structure, and the contributions of such defects to the physical and mechanical properties of the compounds themselves. Only when such information is available shall we be able to understand better why it is that materials of this kind are comparatively brittle and, indeed, we may find that under certain circumstances this brittleness need not be as great as it now appears. Whilst remembering that bonding in oxides is ionic, and that in carbides is covalent, we should still be stimulated in work of this kind by the fact that recently at the University of California single crystals of magnesia have been produced which show considerable ductility at room temperature in bending. Interstitial compounds when produced in a highly pure state may in fact show a range of mechanical properties which will result in the creation of a new class of material of engineering importance and having those attributes in properties which at present are lacking in the hard metals and which would extend usefully their range of engineering applications.

Dispersed Hard Particles

In the 1954 symposium there were papers which described the effect of dispersed hard particles on the strengthening of sintered materials. Two papers dealt with sintered aluminium powder containing dispersed alumina and one with the internal oxidation of copper containing small concentrations of either silicon, beryllium, magnesium, or aluminium. This work has been followed up since, particularly in the United States, where the effects of small quantities of refractory oxides, such as alumina, magnesia, and titania, on the mechanical properties of pure metals, such as nickel and copper, are being studied very actively. It has been shown that when the hard particle is present in a suitable concentration in a highly dispersed form and as particles considerably less than 1μ in size, the material shows considerable resistance to both recrystallization and grain growth. The mechanical properties obtained in these materials at temperatures of the order of 700–750°C are now comparing favourably with certain of the highly alloyed high-temperature materials being used in gas turbines, etc. The selection of the dispersed phase in relation to the matrix is important, as are also the shape and the size of the metal powder particles and the hard-phase dispersion itself. The hard phase should be insoluble in the matrix material in order to ensure that the metallic structure at high temperatures is stable. The techniques of powder metallurgy at the present time undoubtedly offer the most suitable means for obtaining a dispersion of a stable phase of this type. The improvement in resistance to deformation in systems of this kind is associated with the high internal energy introduced into the system by the dispersed hard particles. What is not clear at the present time is whether bonding between the hard particle and the matrix metal is necessary in order to develop the optimum resistance to deformation. Both thermodynamical and electronic considerations will dictate the best choice of system, and, undoubtedly, the interfacial energy which exists between the hard particle and the matrix is likely to influence considerably the behaviour of the dispersed particle and the extent to which it confers upon the material the required resistance to deformation. Studies of the interfaces, therefore, between such particles and solid metals is likely to be of considerable importance in the development of materials of this type. The wetting of refractory compounds both by liquid and solid metals is a matter of interest in a number of fields other than powder metallurgy, and here again powder metallurgy can draw upon experiences gained in these fields in order to develop new materials to its own advantage. This will almost certainly lead to studies of non-stoichiometry and the extent to which wetting is encouraged or discouraged by stoichiometry, or by the presence of adsorbed films on the surface of such particles. Such work also would be of value in the development of cermets where the refractory phase is present in larger bulk than in the case of the dispersed-hardening type of material, whilst its contribution to the further development of bonded materials, such as cemented carbides and other compounds, is probably obvious. Undoubtedly, in work of this kind there is room for the physicist, chemist, and the metallurgist to link hands in their basic and applied research work to the ultimate practical benefit of the industry on a broad front.

CONCLUSION

These are but a few examples which it seemed to me indicated where there was need for a more fundamental approach to certain of the problems in the powder metallurgy industry, and the extent to which the industry can draw upon fundamental work and experience in other fields to its own advantage. There must be many more which will occur to you, perhaps of greater importance than those to which I have referred. I believe, however, that it is to developments arising from work of this kind that we must look for the stimulation which the industry, at least in this country, urgently requires if it is to prosper and compete with the growing pace of technological development in other manufacturing industries. We have to-day created in this country a forum where matters of this kind can be freely discussed. The increased co-operation which this will ensure, not only between powder metallurgists themselves but also between them and metallurgists in other fields, should be mutually stimulating and, I hope, will remove any unnecessary conservatism within the industry which retards development and which, by its removal, need not impair the competitive aspect which in itself is stimulating to a progressive industry.

PAPERS AND REPORTS ON
RESEARCH AND PRACTICE

Metallurgy · Plant Operation · Research

The Driving Rate of Open-hearth Furnaces

By R. W. Evans, T.D., M.Met., F.I.M.

With contributions by
J. H. Chesters, D.Sc.(Tech.), F.Inst.F., A. J. Kesterton, M.Eng., Ph.D., J. F. Allen, and J. Pearson, M.Sc., Ph.D., F.R.I.C.

THE OPEN-HEARTH PROCESS has been virtually the backbone of the steelmaking industry during the last eighty years. The fundamental idea of Sir William Siemens—the achievement of a high flame temperature by using the heat in the products of combustion to preheat incoming gas and combustion air—has been preserved almost unchanged from the early 2-ton furnaces to the present monsters of 350 tons and larger, though economic necessity, such as the abandonment of producer gas in favour of driven fuels, has resulted in some modifications to the original design.

During this time the open-hearth process has continued to be pre-eminent, mainly owing to:

(1) The greater control which can be exercised over the state of oxidation. This, in the face of constant demands for better and more consistent quality, results in greater confidence in the open-hearth product
(2) The ease and consistency with which the phosphorus and nitrogen contents of steel can be kept to low limits
(3) The flexibility of the process in its ability to use varying proportions of scrap and iron
(4) The ability of the process to use varying qualities of pig iron.

The advent of continuous strip mills emphasizes the first and second of these points.

Recent developments in steelmaking have made it necessary to re-assess the open-hearth process, and part of the paper will touch on this subject.

Manuscript received 20th January, 1958.
This paper is to be presented in Liège on 19th June at Technical Session No. 3 during the Institute's Special Meeting in Belgium and Luxembourg.

Mr. Evans is Assistant General Manager (Operations) at the Steel Company of Wales Ltd., Port Talbot, Dr. Chesters is Assistant Director of Research to the United Steel Companies Ltd., Dr. Kesterton is Superintendent of Steel Production for the Steel Company of Wales Ltd., Port Talbot, Mr. Allen is Chief Fuel Engineer of the Consett Iron Co., Ltd., and Dr. Pearson is Assistant Director of the British Iron and Steel Research Association.

SYNOPSIS

The paper first deals with the advantages and disadvantages of the open-hearth process in relation to increasing competition from pneumatic processes.

During the last sixty years, greater production of open-hearth furnaces has been due more to increase in size than to higher outputs per unit of hearth area. Such large furnaces have their operating disadvantages and are costly to build compared with plant for equivalent output by pneumatic processes. Increasing the driving rate of the open-hearth furnace would improve its competitive position in relation to the newer processes which have been boosted by the advent of cheap oxygen.

Further sections of the report deal with certain aspects of increasing the driving rate, including papers dealing with increased fuel rates and use of basic refractories, the use of oxygen for decarburization, the use of oxygen for flame enrichment, and research into factors affecting the driving rate. 1531

The availability of high-phosphorus ores in continental Europe has favoured the basic Bessemer or Thomas process and, where iron containing 1·7–2·0% phosphorus or higher was available, the greater credit for basic slag, together with the lower labour and fuel requirement, made it inevitable that only quality considerations would limit the development of the Bessemer process. Under these conditions, the German pattern of steelmaking developed; this was based on making two qualities of pig iron: Thomas or basic Bessemer iron containing about 2% phosphorus, and low-phosphorus *stahleisen* containing about 2% manganese. The Thomas iron is blown in basic converters and the mill scrap arising is melted in open-hearth furnaces, together with low proportions of *stahleisen*. Thus, the average integrated works makes both open-hearth and Bessemer steel which, from the quality angle, would cover a large range of products, and, although there are limits to the quantities of scrap which the air-blown converter can consume, some flexibility in the overall scrap/iron ratio can be effected in the open-hearth department. So far, the Thomas process was limited to irons containing not less than about 1·8% phosphorus, and the acid Bessemer process to iron containing not more

than 0·06% phosphorus. In neither process could the nitrogen content be kept much below 0·012%. There remained a wide range of phosphoric pig irons which could not be treated in pneumatic processes; on the other hand they could be readily utilized in open-hearth furnaces of the fixed and tilting variety to produce steels containing not more than 0·005% nitrogen.

During the last twenty years, and particularly during the last ten years, economic and technical factors have reacted in a way favouring the pneumatic processes (and to some extent the electric furnace process) at the expense of the open-hearth. Some of these developments are described in the following sections.

Development of the Open-hearth Process Itself

During this period the main cause of increased output of the open-hearth furnace has been by increase in size of units rather than any spectacular increase in the driving rate of a given-size furnace. Indeed, the average tap-to-tap time[1] to-day of U.S. open-hearth furnaces is little, if any, better than was achieved at the turn of the century at Homestead, where, in melting shops containing twenty 50-ton furnaces producer-gas driven and arranged in two banks of ten on each side of a common casting pit, the average output on a six-day week was 16 charges per furnace using 50% hot metal of approximately the same composition as is used to-day. On occasion, up to 23 charges per week were obtained in this plant. Nevertheless, it has to be remembered that the advent of the strip mill has brought with it a greatly increased requirement for low-carbon, low-sulphur steel, which, other things being equal, results in longer refining times. This led to restrictions on bath depth in an effort to achieve as high a slag/metal interface area per ton as possible. Larger hearth areas inevitably resulted in increased requirements of floor space per ton of furnace capacity. Incidentally, the larger hearth area also enabled more scrap surface to be exposed to the flame which, provided that more fuel was introduced, accelerated the melting rate.

However, while large increases in capacity have enabled more steel to be produced, they have not been wholly advantageous for the following reasons:

(*a*) Single ladle charges of 250–300 tons require massive cranes, gantries, and buildings, so that now an open-hearth plant of fixed furnaces costs nearly 50% more than a basic Bessemer plant, whether top- or bottom-blown, of equivalent capacity. In days of dear money this is an important consideration when one is deciding whether to install open-hearth furnaces or some form of pneumatic process.

(*b*) Bunching of tapping times of such large heats, compared with the more modest electric furnace or Bessemer charges, whose tapping times can in any case be more precisely controlled, places periodic loads on the soaking pits and so larger installations are required; the higher capital cost of these should, in reality, be added to the open-hearth capital cost.

If, by increasing the driving rate of open-hearth furnaces, the same production can be achieved with fewer units, the capital cost and the operating cost may be decreased; also less ground space will be required per annual ton.

Lower-nitrogen Steels from the Thomas Process

Even before the 1939–45 war, the bad effect of high nitrogen in Bessemer steel was recognized, and processes such as the H.P.N. were put into operation to decrease the nitrogen. It was recognized that by substituting part of the oxygen requirement from air by iron ore, less air and therefore less nitrogen were needed; at the same time control of the finishing temperature in the vessel decreased nitrogen pick-up and as a result of the application of both these methods it was possible to produce steel containing under 0·01% N_2.

Use of Oxygen in Pneumatic Processes

The advent of tonnage oxygen has had a tremendous effect on the situation. By enriching the blast up to 25% of oxygen (or higher), not only could the nitrogen content be further reduced, but also more scrap or iron ore could be used as a coolant, with economic advantage. In further development, nitrogen is eliminated from the blast altogether, by using mixtures of oxygen and steam, or oxygen and carbon dioxide; under these conditions nitrogen contents lower than those obtainable in the open-hearth can be achieved.

The use of oxygen has also considerably speeded up the processes, so that heats can be blown now in little more than half the time previously required; on the other hand, these fast conversions have decreased the control of quality, but it must be said that the development of instruments is proceeding fast to solve at least some of these control problems.

It should be noted that in general, where before the introduction of oxygen a minimum phosphorus content of about 1·7% was required in the pig iron, this figure could be reduced to 1·3–1·4% and even less afterwards, thus making available to the Bessemer process a wider range of iron, though the lower credits for basic slag partly offset this advantage.

Rise of the Top-blown Oxygen Process

Another formidable competitor to the open-hearth process resulted primarily from cheap oxygen. The L–D process, developed in Austria, enabled pig iron containing up to about 0·3% P to be used in a converter vessel for making steel, the capital cost of such a plant being relatively low. By far the greater part of the world's known reserves of iron ore will produce pig iron suitable for the L–D process and thus, almost overnight, the vast U.S. steel industry for the first time found a pneumatic process which could satisfactorily be applied to practically all its pig iron; the same can be said of India, South Africa, Australia, the South American countries, and probably also Russia and China.

Other Oxygen Processes

Considerable attention has been paid in Europe to the development of a pneumatic process for treating phosphoric iron in the "gap," i.e. containing 0·3–1·3% P. This has led to the development, for instance, of the Kaldo process, which is capable of making steel from a wide range of iron compositions, and with more precise control than is possible in a bottom-blown vessel. Somewhat similar is the Rotor process developed at Oberhausen.

Comparative Fuel Economy

In previous papers the author has classified the electric furnace and open-hearth processes as "applied heat processes" and the pneumatic processes as "exothermic heat processes," which highlights the essential difference between these steelmaking techniques. The exothermic heat processes have the undoubted advantage of using, as fuel, combustible elements in the pig iron such as silicon and phosphorus, which have been reduced chemically from their inert oxides in the ore by the energy contained in the coke. This fuel, in fact, in addition to working the blast-furnace, provides the source of heat for the steelmaking conversion in the pig iron. Indeed, the potential heat stored in carbon, silicon, and phosphorus, and liberated by their oxidation, is far more than is required for converting the pig iron into steel so that coolants such as scrap or iron ore are additionally required to control the process temperature. The heat efficiency of conversion is considerably greater in these processes than in the open-hearth process.

Availability of Energy

The prospects of the open-hearth are in no way improved when one considers the possibility in the next two or three decades of electric energy becoming cheaper, and 'fossil' fuel energy, particularly that of fuel oil, becoming dearer. This trend would result in still cheaper oxygen, which would in itself favour the pneumatic processes. While coal may be economically available for many years to come, its use for fast open-hearth steelmaking is not likely to be competitive with pneumatic processes, so that as the price of fuel oil energy increases compared with electric energy, so the economy of open-hearth steelmaking will deteriorate.

Indeed, the U.S. Atomic Energy Commission[2] has forecast a date around 1975 when the price of fuel oil, owing to its dearth, will be rising. If the life of an open-hearth plant is considered to be about 30 years, the possibility is that a new plant which must depend on fuel oil for its heat may be relatively uneconomic during the last ten years of its life. Coke-oven gas, tar, and pitch may last longer.

It is evident, therefore, that the open-hearth process is up against ever-increasing competition from the newer pneumatic processes. Whereas its flexibility, and its predominating ease of control and consistency of steel quality are admitted, it is now necessary, while maintaining these advantages, to increase the driving rate so that the overall economy of the process can also be maintained. It appears certain that we have in no way arrived at the limits of the rate of driving, i.e. the tons/hour for a given hearth area. The advent of cheap oxygen is helping open-hearth operators, enabling higher fuel inputs to be maintained. This will highlight refractory problems of those parts of the furnace exposed to the flame or to the hot products of combustion. Greater heat transfer from the flame to the charge must be achieved in order to melt faster, and, when the charge is under cover, faster rate of refining must be sought. The lower the metallurgical load the better, but where high metallurgical loads have to be carried, improved methods of flush-slag practice should be adopted.

In order to show in greater detail results which have been obtained by new techniques and the trend of thought in the U.K., separate papers have been devoted to some of the more important of these aspects in the driving rate of open-hearth furnaces.

These contributions are as follows:

"*Increased Fuel Input and Basic Refractories*," by J. H. Chesters, D.SC.(TECH.), F.INST.F. (Assistant Director of Research, The United Steel Companies, Ltd.).

"*The Use of Oxygen for Decarburization in the Open-hearth Furnace*," by A. J. Kesterton, M.ENG., PH.D. (Superintendent of Steel Production, The Steel Company of Wales Ltd.).

"*Use of Oxygen to Assist Combustion in the Open-hearth Furnaces at Consett*," by J. F. Allen (Chief Fuel Engineer, Consett Iron Co., Ltd.).

"*Research Into Factors Contributing to the Output Rate of Open-hearth Furnaces*," by J. Pearson, M.SC., PH.D., F.R.I.C. (Assistant Director, British Iron and Steel Research Association).

The author wishes to express his thanks and gratitude to the above contributors for their readiness to undertake the work.

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Increased Fuel Input and Basic Refractories

By J. H. Chesters, D.SC. (TECH.), F.INST.F.

The new basic oxygen processes, in particular the L–D, the Rotor, and the Kaldo, are already providing the biggest stimulus to development of the open-hearth that this furnace has experienced since it was first built about a century ago. The stimulus arises from the claim that these processes are capable of making open-hearth quality steel at a far greater rate per square foot of foundation area and at a lower final cost. It has also been suggested that they can do so with a very much lower capital cost per ton of capacity, but this statement is doubtful if due allowance is made for the lower availability of certain of the plant and of the considerable quantity of ancillary equipment (e.g. mixers and fume removal plant) required.

Until recently it was often suggested that there was an optimum fuel input for every open-hearth furnace and that once this figure was exceeded fuel costs rose rapidly. With producer-gas furnaces, where mixing rate is completely determined by port areas and available pressures, this may well have been true. With high-pressure gas or atomized liquid-fuel furnaces, however, no such simple relation exists. The amount of fuel that can be burnt efficiently depends on numerous factors, many of which are capable of modification during a furnace campaign. Thus, where 100-ton furnaces of 450 ft² hearth area were once run with a maximum fuel input of 300 gal, they are now run more economically on 400 gal, and have been shown to do equally well on 500 gal. Nor do we

consider this the limit, for with modern techniques 1000 gal, or indeed several times as much, could be burned in the combustion space available without any unburnt gases passing into the downtakes. Whether heat transfer can keep pace with fuel input is, of course, another matter, but there is no theoretical reason why fuel consumption per ton should increase and some justification for expecting that it should decrease because of reduced percentage losses through brickwork. Thus in a recent trial on a 100-ton furnace in the Templeborough shop at Steel, Peech and Tozer, an increase in maximum fuel input from 375 to 500 gal—an average increase of 32%—gave a 32% increase in output, i.e. fuel consumption per ton remained constant although no preliminary study had been made of the best conditions for handling such increased firing rates.

Merely to increase the oil and steam flow to a furnace may, however, be inadequate; other changes (e.g. the use of multiple burners to give better bath coverage and more even temperature distribution) must be considered, together with the use of refractories capable of surviving the higher temperatures in furnace chamber and regenerative system. In the trial mentioned above a basic roof was used, but trouble was experienced with refractories in the slag pockets, where silica construction was still employed. The use of super-duty silica bricks, either in this position or in the main roof, although giving a somewhat longer life under standard operating conditions, only increases the safety factor by about 10° C. For really hard driving, therefore, recourse must be made to basic refractories, which can be used at much higher temperatures. Meanwhile, something can be done to reduce the stress on the linings, by application of the researches carried out during the last ten years on flow pattern, mixing pattern, and the factors controlling iron-oxide deposition and temperature distribution.

The All-basic Furnace

Recent trials show that with such high firing rates, roof temperatures may be above the critical point (1650° C) for as much as three hours in eight of the charge-to-tap time. Occasionally the temperature rises to 1800° C, whilst even higher temperatures can be expected where oxygen enrichment is used. Incidentally, trial furnaces are already operating, both in Germany and in the U.S.S.R., where air is completely replaced by oxygen. Under such conditions all-basic construction is not merely desirable but essential. About half the open-hearth furnaces in Russia and Germany now have basic roofs, whilst in the U.K. and the U.S.A. interest is rapidly building up, certain of the largest furnaces having already been converted to basic construction. In spite of the very severe operating conditions, the lives obtained are roughly twice those given by silica roofs. This is not, however, sufficient to pay for the more expensive bricks, except in the U.S.S.R., where the price ratio of chrome-magnesite to silica appears to be only half that obtaining elsewhere in Europe and the U.S.A. In order to be economic this additional cost must be offset by credits for increased output per hour, or fuel savings per ton of steel made. The numerous cost data available on all-basic furnaces suggest that a minimum increase of 10% in driving rate is usually required unless allowance is made for the profit on the extra steel made.

The factors controlling roof life on all-basic furnaces have been the subject of an immense amount of research and of numerous co-operative trials. Certain properties, notably volume stability at high temperatures, refractoriness-under-load, and thermal shock resistance, appear to be important, but no marked improvement has yet been made on the best prewar chrome-magnesite brick, in which the chrome formed a coarse fraction (60–70% of the total), while the magnesite was present as fines (30–40%). The only new development in recent years has been the so-called 'Double E' brick, which is essentially an unfired metal-cased basic brick with two additional steel plates inserted in it. This has the effect of reducing the cross-sectional area of the units to only a third of normal, which in turn should increase the resistance to spalling, brick size being one of the few factors that seems to have a marked effect on the rate at which one face of a brick can be heated up without crack formation. The relative lives obtained with particular types of brick appear to vary appreciably from furnace to furnace, and on a given furnace different qualities may give lives varying by as much as 2 : 1. Other factors are, however, known to be important—e.g. furnace design, method of roof suspension, metallurgical load, and operating procedure. There would appear to be two dominating factors governing the general economy of all-basic furnaces—driving rate and temperature fluctuations in service.

The Use of Oxygen for Decarburization in the Open-hearth Furnace

By A. J. Kesterton, M.ENG., PH.D., F.I.M.

Mechanisms of Carbon Oxidation and Heat Transfer

Larson[1] suggests that reaction between carbon and oxygen atoms occurs only at the surface of gas bubbles, and that surrounding a bubble there is a very thin stagnant film across which the atoms must move relatively slowly by diffusion to the reaction zone. Additionally, oxygen is assumed to enter the metal by diffusion across thin stagnant films at the slag/metal and gas/slag interfaces. Decarbonization rate is therefore controlled by oxygen diffusion velocities across two or three stagnant films at phase boundaries, and by the rate of bubble nucleation.

Therefore oxygen injection causes considerable acceleration. Gas bubbles are provided additional to nucleation at the hearth surface. Oxygen is supplied inside the bubble, and diffuses across only one instead of two or three stagnant films, and at a fast rate owing to the high oxygen concentration. The more vigorous boil thus stimulated also circulates unreacted carbon rapidly to the bubble surfaces.

Downward heat flow to the steel bath is assumed to occur by relatively slow conduction across thin stagnant films at the gas/slag and slag/metal interfaces, and by turbulent mixing in the remainder of the slag and metal layers. Inadequate carbon boil causes heat which gets across the boundary films to continue transferring slowly by conduction rather

than quickly by turbulent convection. Heat flow is also stimulated by ability to provide adequate hot excess air, to burn the reaction gas CO, since high-temperature heat is generated immediately above the slag, with considerable downward driving force.

Heat transfer is therefore greatly accelerated by oxygen injection, since the boil and turbulent mixing are immensely stimulated. High-temperature heat is produced by carbon–oxygen reaction at the bubble surfaces, thus bypassing conduction across stagnant films at gas/slag and slag/metal interfaces. Fuel input can be reduced, releasing regenerator capacity to provide hot excess air for burning the CO.

Application of Oxygen

Oxygen is applied either by means of bare steel lances injecting oxygen near the slag/metal interface, or by impingement from above the slag via water-cooled jet probes, and in both cases largely for decarburization subsequent to clear melting. Difficulties arise at earlier stages in the heat, mainly owing to the vigour of the reaction, which may cause damage to the roof, and also to atmospheric pollution by red fume.

Clearly, however, oxygen will accelerate both decarburization and heat flow during the longer period from hot metal addition onwards, resulting in greater gains. At several steelplants, work on these lines has been carried out, but remains unpublished. However, moderate oxygen flows have produced remarkable results—25% increases in production, and in isolated experiments outputs up to 60 tons/h achieved. An adequately checkered open-hearth furnace, capable of early slag removal and operated for early bath oxygen injection, would make high-quality steel at fast speeds, and with good fuel economy from a very wide range of burdens expressed in terms either of hot-metal/scrap ratio or metallurgical load measured by phosphorus and silicon in the hot metal. The open-hearth furnace could remain competitive in future with other steelmaking units, particularly those incapable of melting much scrap, or having no heat-salvaging equipment such as checkers or waste-heat boilers.

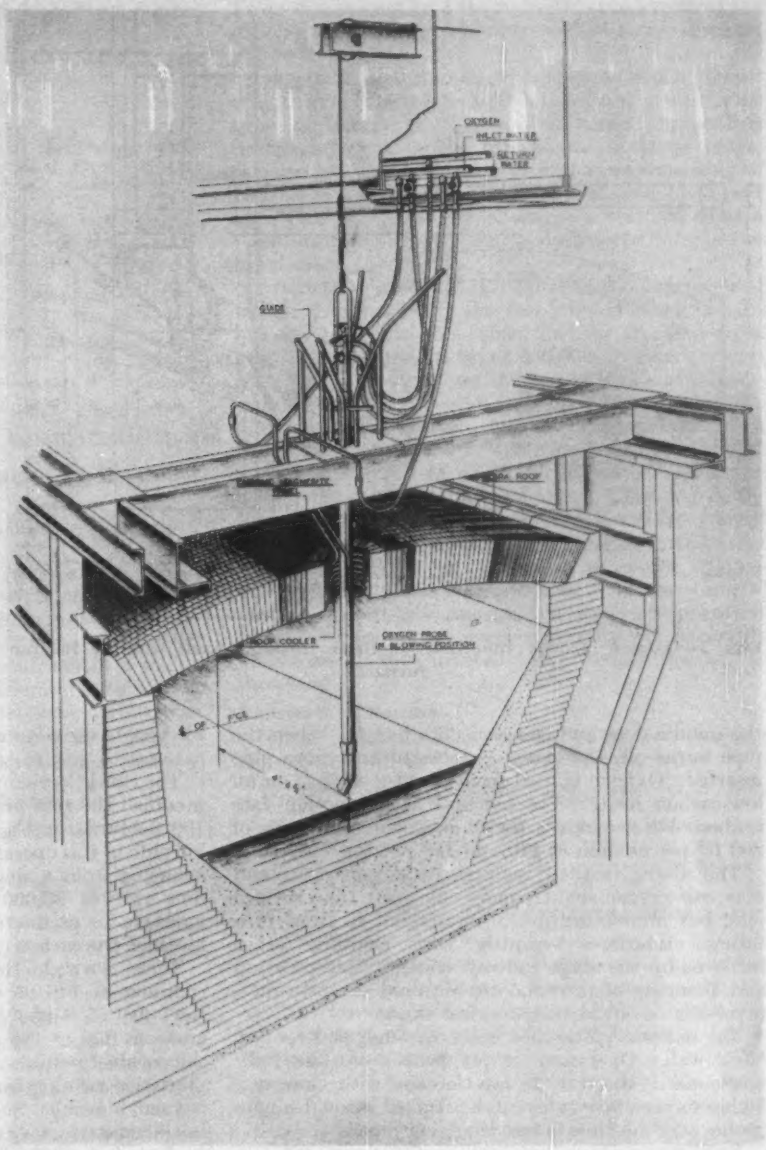

Fig. 1—Roof-mounted oxygen probes on 200-ton furnaces at Abbey Works

Therefore development of the use of oxygen for early bath application should be pressed forward. The associated problems probably include development of the basic roof, effective methods of keeping checkers clean, and installation of fume-extraction equipment.

Practical Methods and Results

Bare steel lances for injection close to the slag/metal interface are used at the Inland Steel Company, U.S.A.[2] Oxygen is applied by means of 1-in. bore lances, at a rate of 36,000 ft^3/h and a pressure of 80 lb/in^2. The lance is slid through the wicket hole in

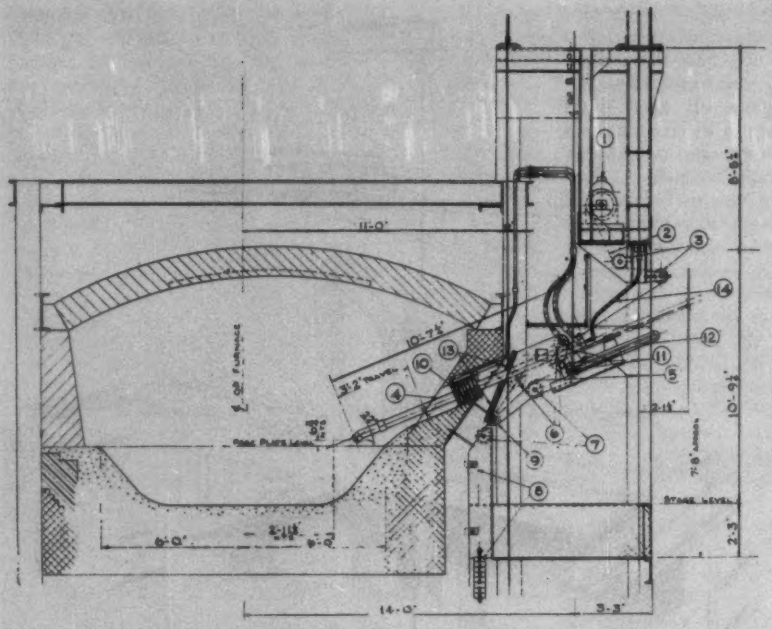

Fig. 2—Oxygen probes modified to enter through back wall of 100-ton furnaces

the middle door and clamped on a buggy. When the pipe burns off, the clamp is released and more pipe inserted. Oxygen is used from about 0·40% C on all low-carbon heats. The increase in production rate is about 1·0 net tons/h, for an oxygen consumption of 200 ft³ per net ton in 140 and 180 net ton furnaces.

The above method requires little apparatus and may use oxygen slightly more efficiently than surface jets, but immobilization of equipment in front of a furnace interferes seriously with charging other furnaces by the stage railway system. Manipulation and changing of the tube are required several times, involving inconvenience and lost time.

The surface jet probes enter through the roof or back wall. Operation of jet probes can be fully mechanized, there is no interference with charging, higher oxygen flow rates can be applied through single probes, and no time is lost changing pipes.

Roof-mounted probes are installed in 200-ton furnaces at the Abbey melting shop of the Steel Company of Wales Ltd.[2] (Fig. 1). Oxygen is normally used after clear melting, at any carbon level up to 0·50%, the flow rate being about 40,000 ft³/h at 0·50% C, increasing to 60,000 ft³/h as the carbon falls. A specific volume of oxygen proportional to the initial carbon content reduces the bath carbon to the level of 0·05% required for sheet steel, and refining can proceed without further analysing for carbon. The carbon oxidation rate is accelerated in a ratio of 3 to 1. From 0·40% C, the refining time is reduced by 95 min, and from 0·10% C by 40 min.

Although refining time is reduced to one-third of normal, the sulphur elimination rate increases proportionately, and there is no significant difference between average ladle sulphur analysis for oxygen and non-oxygen heats. A slag control system is also employed, using oxygen to accelerate sulphur elimination, when producing low-sulphur steels (0·027% S). Lime and hot metal additions and oxygen flow rates are proportioned to the analysis for carbon and sulphur at melt, to provide rapidly a fluid slag of adequate basicity and the necessary amount of slag/metal interfacial exchange by means of an accelerated carbon boil.

The same type of roof-mounted probe has been used by the Steel Company of Canada Ltd.,[4] in a 250 net ton furnace. Consuming 153 ft³ per net ton, the oxygen heats achieved a 45-min reduction in tap-to-tap time, a reduction in fuel consumption from 3·851 to 3·464 million B.t.u. per net ton, and a lower ladle carbon analysis of 0·057% compared with 0·072%. Both melt and ladle sulphur analyses were the same, 0·030%, though the oxygen heats were aimed to melt 0·30% higher in carbon, to ensure sulphur removal.

The Steel Company of Wales Ltd. have successfully modified the roof probe to enter via the back wall in 100-ton furnaces (Fig. 2). The probes have an unusually long life in this operation, up to 404 heats having been achieved from a single unit. The maximum oxygen flow rate is 30,000 ft³/h. Oxygen is particularly valuable for production of silicon steel electrical sheet in which the carbon content is 0·025–0·030%.

There is a reduction in refining time of 35 min for rimming steel (0·05–0·06% C), and 75 min for silicon steel (0·025–0·030% C at tap). A saving in pitch creosote fuel of 180 gal for rimmers and 340 gal for silicon steel can also be made, by a combination of shortened refining time and reduced fuel input during oxygen blowing. Sulphur elimination is unaffected. In silicon steels, for example, the average ladle sulphur analysis is 0·026% for both oxygen and non-oxygen casts.

At the Zaporozhstal works in Russia[5] two simultaneously blown roof-mounted probes, opposite Nos. 2 and 4 doors, have been used in a 185-ton furnace. The probe was immersed to a depth of 250 mm in 25 heats, and held 100–200 mm above the slag in four heats. Above 0·8% C the optimum oxygen flow rate to give a controllable reaction was 25 m³/min at a pressure of 5·5 atm, the decarburization rate being 1·8% C per hour. At 0·15–0·09% C, the optimum flow rate increased to 35 m³/h at 7·5 atm, the decarburization rate being 0·35% C per hour.

The waste-gas dust content increased sharply with carbon content, but compared with jetting from above the surface, immersion to a depth of 100 mm markedly

reduced the entrainment (e.g. from 7 g/m³ to 2·8 g/m³, when blowing at 0·25% C).

The average temperature rise during blowing was 125° C per hour.

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Use of Oxygen to Assist Combustion in the Open-hearth Furnaces at Consett

By J. F. Allen

During the first quarter of 1957, 48·5% of the charges made at the melting shop consisted of a high proportion of scrap. These charges are referred to as "maximum scrap charges" and consist of 120 tons of scrap, 50 tons of hot metal, and 3·5 tons of cold metal. Investigations carried out during 1953 on this type of charge showed that the two factors affecting the working rate of such charges were:

(1) Fuel carried during the charging and charge-to-melt period.
(2) Total charging time of the furnace.

The following table illustrates the effect of fuel rates on working rate:

Therms per hour for 6 h after Commence Charging	Charge-to-tap Working Rate, tons/h
650	8·8
700	10·3
750	12·6
775	15·0

The furnaces working at Consett Iron Co. had initially been of 80 tons capacity and, whilst improvements had been made to the laboratory of the furnace, little had been done to increase checker capacities and flue sizes.

The present furnaces have a bath length of 47 ft and a width of 15 ft. The regenerator chambers have about 4000 ft³ of checkerwork and the main exhaust flue on most furnaces is only about 26 ft². This construction led to severe limitations on the quantity of fuel which could be burned in the furnace. By using oxygen to assist combustion it was possible to burn more fuel in the furnace, with a consequent increase in output.

Oxygen Technique

As a result of satisfactory trials conducted during August, 1954, it was decided to erect a tonnage oxygen plant so that all open-hearth furnaces could be supplied with oxygen to assist combustion. A 100-tons/day tonnage oxygen plant has been completed and supplies of oxygen are fed into a main distribution and storage system in the works, at a pressure of 600 lb/in². From this system an 8-in. main runs the length of the melting shop from which oxygen is fed to the furnaces at 150 lb/in².

Oxygen is used mainly with charges which consist of 120 tons of scrap and 50 tons of hot metal. This type of charge, a "maximum scrap charge" is designated M.S. in the tabulations in these notes. Oxygen has also been used with charges consisting of 80 tons of scrap, 50 tons of hot metal, and 45 tons of blown metal. This type of charge is referred to as a "semi-duplex charge" and is designated S.D. in the tabulations.

After the furnace has commenced charging and within the first hour, the fuel supply is set to give 850 therms/h from the mixed fuel tar and coke-oven gas. The air supply is set at 800,000 ft³/h and oxygen is turned on to the 'live' burner at a rate of 30,000–40,000 ft³/h. The oxygen is delivered through a 1-in. dia. water-cooled lance located immediately below the combined tar and coke-oven gas burner, or through a 1-in. dia. pipe in a combined water-cooled tar, coke-oven gas, and oxygen burner. Charging of the furnace proceeds as quickly as possible and the charged material is piled in front of the 'dead' burner so that a large mass of scrap is presented to the oxygen-enriched fuel stream on reversal. At the time of writing these notes, the oxygen supply is operative for about 4 h, but as increased supplies become available both the flow rates and duration of flow will be increased.

Summary of Results

Three main effects of the use of oxygen to assist combustion will be considered in this section.

(1) Effect on the charge-to-melt period when using oxygen.
(2) Factors affecting the charge-to-tap working rate of the furnace when using oxygen.
(3) Effects on the overall charge-to-charge working rate of a furnace when using oxygen.

Effect on the Charge-to-Melt Period when Using Oxygen

The use of oxygen during the charging period has reduced the charge-to-melt times considerably; the average decrease is of the order of 1¾ h. The following are some typical figures for furnaces before and after the application of oxygen:

Furnace	Without Oxygen	With Oxygen
C	9 h 10 min	7 h 30 min
E	9 h 30 min	8 h
G	9 h 45 min	7 h 40 min

It is of interest to note that charge-to-melt times secured on 'old' furnaces with oxygen were at least equal to charge-to-melt times on 'new' furnaces without oxygen. The use of oxygen towards the end of a furnace campaign has had a beneficial effect on the working rate. On average, the use of oxygen has enabled the charge-to-melt period to be reduced by 20%. With higher flow rates than indicated, reductions of 30% have been obtained.

Factors affecting the Charge-to-Tap Working Rate of a Furnace when Using Oxygen

The following table illustrates the effect of delaying the application of oxygen into the furnace during the charging period:

Table I
MAXIMUM SCRAP CHARGES

Fce.	Charge-to-Charge Working Rate, tons/h				Gain in Working Rate, %
	Without Oxygen	Rate	With Oxygen	Rate	
C	9.1.54 to 12.6.54 26.6.54 to 13.11.54 (45 weeks)	11·3	19.2.55 to 14.6.55 18.6.55 to 8.10.55 29.10.55 to 28.7.56 25.8.56 to 29.12.56 (89 weeks)	13·2	16·8
E	15.5.54 to 29.9.54 2.10.54 to 1.1.55 (32 weeks)	11·7	13.8.55 to 14.1.56 28.1.56 to 17.11.56 24.11.56 to 29.12.56 (67 weeks)	13·1	11·9
F	31.7.54 to 11.12.54 1.1.55 to 15.4.55 (37 weeks)	10·8	23.4.55 to 13.8.55 22.8.55 to 31.3.56 21.4.56 to 29.12.56 (92 weeks)	13·0	20·4
G	29.5.54 to 30.10.54 13.11.54 to 5.3.55 (37 weeks)	11·3	12.3.55 to 23.7.55 13.8.55 to 24.12.55 7.1.56 to 29.12.56 (89 weeks)	12·8	13·3
	Average values	11·28		13·03	15·5

Time of Oxygen Admission into Furnace after Commence Charging, h	Charge-to-Tap Working Rate, tons/h
Up to 1	19·4
1–2	19·0
2–3	18·6
3–4	18·2

It will be seen that in order to gain the maximum benefit from oxygen enrichment, it should be admitted to the furnace as soon as possible after the charging has commenced.

The effect of increasing the oxygen flow rate into the furnaces is shown by the following figures:

Oxygen per Ingot ton, ft³	Charge-to-melt Period
800	7 h 10 min
900	6 h 45 min
1000	6 h 10 min

The working rate of the furnace increases progressively as the oxygen flow rate is increased. Trials conducted initially at an oxygen usage rate of 800 ft³/ton resulted in severe wear on the roof above the burner and also in the checker systems. However, the introduction of 53–54% alumina bricks for the top six courses in the checker systems has virtually stopped severe checker brick erosion, whilst the introduction of a basic checker brick in one furnace gave double the normal checker life. By still further improving the quality of the roof blocks it should be possible to enjoy the benefits of high oxygen flow rates. It would appear that a basic roof would be justified on a furnace using oxygen to assist combustion, so that a faster charge-to-melt period could be obtained by virtue of the higher flame temperature developed from greater enrichment values.

Effect on the Overall Charge-to-charge Working Rate of a Furnace, When Using Oxygen

Tables I and II show the overall gain in the charge-to-charge working rate for campaigns with and without the use of oxygen for flame enrichment. The dates given refer to the campaign period.

During some of the campaigns shown, considerable restriction on oxygen supplies had to be exercised because of major plant failure at the oxygen supplier's works. As a result of this, performance figures during these periods will be less favourable than if oxygen supplies had been available. The figures listed in the tables are 'run of shop' results and no attempt has been made to assess the relative incidence of process hazards during the campaigns before and after the application of oxygen (e.g. restriction of oxygen supplies, production delays caused by various means, etc.).

For the first quarter of 1957 the charge-to-charge working rate averaged 13·2 tons/h. This represents a gain of 17% in working rate.

It is interesting to note that the charge-to-charge working rate of the M.S. charges with oxygen is about equal to the S.D. charges without oxygen, i.e. the effect of oxygen on the working rate with M.S. charges equates overall to the effect of using 50 tons of blown metal in the S.D. charges.

Conclusions

(1) With adequate supplies of oxygen available to the furnaces it is considered possible to increase further the working rate of M.S. and S.D. charges up to 25%.

(2) Checker brick attack can be countered by laying the top six courses or more with 53–54% alumina bricks.

(3) Roof life has been reduced by about 6%, but it is considered that by the use of better roof blocks or a basic roof the use of oxygen would prove of no major detriment to roof life.

(4) Fuel consumption when using oxygen to assist combustion has been reduced by about 15%.

Table II
SEMI-DUPLEX CHARGES

Fce.	Charge-to-Charge Working Rate, tons/h				Gain in Working Rate, %
	Without Oxygen	Rate	With Oxygen	Rate	
C	9.1.54 to 12.6.54 26.6.54 to 13.11.54 (45 weeks)	12·9	19.2.55 to 14.6.55 18.6.55 to 8.10.55 29.10.55 to 28.7.56 25.8.56 to 29.12.56 (89 weeks)	14·2	10·1
E	15.5.54 to 29.9.54 2.10.54 to 1.1.55 (32 weeks)	14·2	13.8.55 to 14.1.56 28.1.56 to 17.11.56 24.11.56 to 29.12.56 (67 weeks)	16·1	13·4
F	31.7.54 to 11.12.54 1.1.55 to 15.4.55 (37 weeks)	12·5	23.4.55 to 13.8.55 22.8.55 to 31.3.56 21.4.56 to 29.12.56 (92 weeks)	15·3	22·4
G	29.5.54 to 30.10.54 13.11.54 to 5.3.55 (37 weeks)	13·4	12.3.55 to 23.7.55 13.8.55 to 24.12.55 7.1.56 to 29.12.56 (89 weeks)	14·4	7·5
	Average values	13·25		15·0	13·2

Research into Factors Contributing to the Output Rate of Open-hearth Furnaces

By J. Pearson, M.SC., PH.D., F.R.I.C.

Research aimed at improving the output rates of open-hearth furnace may be directed in two ways, if we leave out of consideration the mere enlargement of furnace capacity and changing the type of raw material that the steelworks uses, problems of which will generally be specific to each installation.

Faster working rates may be brought about by modifying the mode of action of the furnace or by pretreating the charge materials so as to reduce the metallurgical load on the furnace. The British Iron and Steel Research Association, in collaboration with its member firms and other research institutes, has been investigating both of these aspects for a number of years and the following brief account describes the main lines of attack and the results obtained.

Furnace Design

The principal target of aerodynamic studies has been that of increasing furnace life, which is an indirect way of obtaining greater annual outputs, rather than that of increasing the driving rate *per se*. The technique used has been to build reduced scale models of existing or planned furnaces and to carry out surveys of gas and liquid flows within them under conditions simulating as closely as possible those of working units. These studies have been supplemented by dust deposition tests (in which dust has been added to the fluids passing through the model), in order to discover how slag and iron oxide deposition on working surfaces depends on the flow pattern within the furnace.

In general, these investigations have been diagnostic, but by correlating the results obtained with practical experience, it has been possible to recommend minor variations in furnace shape and, more particularly, the orientation of burners, that lead to reduction of excessive and premature refractory wear. It is to be hoped that such studies will indicate how a furnace may be heated with the lowest overall roof temperature, for a given fuel supply, and so lead to the possibility of increasing firing rates appreciably.

Combustion Conditions

In so far as fuel is burned to heat the charge and because regenerators do not permit complete recovery of the heat in the waste gases, the function of a burner is to induce complete combustion within the furnace laboratory in such a way that the best heat transfer conditions obtain. Investigations have indicated the important factors influencing combustion.

Liquid Fuel Burners

Theoretical and practical studies have shown that the length of liquid fuel flames is determined solely by the distance travelled by the fuel before it has entrained sufficient air for complete combustion.[1] This means that the rate-determining process is neither a chemical combination nor an evaporation, but simply one of physical mixing by turbulent diffusion. It has also been shown that the mixing length of a liquid fuel jet is directly related to the jet thrust or momentum. The function of a burner for driven fuel is therefore that of producing the correct momentum for a desired fuel input for a given flame length. The burner should convert the energy of the steam or air used for 'atomizing' into momentum with the smallest possible loss.

The B.I.S.R.A. burner was designed on this principle. To the steam pipe is fitted a convergent–divergent nozzle of a size and shape that makes use of the full steam pressure available; the liquid fuel is fed in through a concentric tube within the steam pipe. With such an arrangement it is possible to obtain efficiencies of the order of 60–75% of the maximum thrust obtainable. The best theoretical shape of nozzle gives the highest efficiency, but nozzles of simpler construction are still adequate for practical purposes.

A comparison of a B.I.S.R.A. burner with a back-end atomizing burner has been carried out. It was found that for equal oil flow, steam flow, and steam pressure, the B.I.S.R.A. burner gave a shorter flame but presented no difficulties in obtaining a long flame. The B.I.S.R.A. burner gave a 5% higher melting rate and thus allowed a higher charging rate, the net result being an increase in hourly production rate of 3%. Because of the more efficient combustion, there was a reduction in fuel consumption of 5% and, what was not expected, after one year's operation on four furnaces, there was less furnace wear.

The following table, taken from the records of a 100-ton fixed furnace[4] working all cold charges, also indicates the advantages to be gained when using the B.I.S.R.A. burner :

	Average Weekly Output, tons	Fuel Rate, 10^6B.t.u./ton
Mixed blast-furnace and coke-oven gases	959	8·26
1*st Campaign*, Conventional burner, 34·2% oil and 65·8% C.O. gas	1072	7·38
2*nd Campaign*, Conventional burner, 38·1% oil and 61·9% C.O. gas	1135	7·16
3*rd Campaign*, B.I.S.R.A. burner, 34·3% oil and 65·6% C.O. gas	1185	6·3

Producer-gas Burners

It is to be expected that a greater degree of control of the combustion of producer gas could be achieved if it were possible to use supplementary momentum producing controls. To this end, water-cooled air guns have been introduced into the ports of two acid open-hearth furnaces. Methods for the correct and most convenient placing of the guns have not yet been discovered, but there is evidence that the thrust produced by the air jets makes combustion more efficient within the laboratory. Reduction of charging and melting times of up to 30 min have been obtained. Further work on this aspect is needed.

Pretreatment of Charge Materials

The production rate of open-hearth furnaces is determined to a large extent by the time required to remove the unwanted impurities and to raise the temperature of the metal to a suitable tapping temperature. The use of pretreated blast-furnace metal offers advantages in both these respects. If

the impurity content is low, there is a smaller 'metallurgical' load on the furnace and the lower amount of slag produced will require less heat to raise it to working temperature; as a result of the thinner slag blanket, heat transfer between flame and bath will be improved. Little can be done to pretreat steel scrap but techniques are now available for removing silicon, and phosphorus and carbon from hot metal.

Pretreatment is often carried out in active mixers, using iron ore and lime, but the rates of removal of silicon are so slow that the composition of the metal taken from the mixer is in some cases not very different from that charged to it. The advent of tonnage oxygen has provided a means whereby this limitation can be removed. Experiments at U.K. works have established a workable technique for lancing blast-furnace metal with oxygen in a basic-lined ladle to lower the silicon content appreciably and this technique is becoming generally accepted by the industry. The quantity of metal treated varies from 15 to 60 tons, depending on works' requirements, and the proportions of slag-making materials and oxygen used varies with the silicon content of the metal. Not only does the treatment reduce the silicon content of the metal but it also raises its temperature, which further adds to the working rate of the furnace. Increases in production rate of up to 20% have been claimed for pretreated as against mixer metal.

In so far as phosphorus also adds to the metallurgical load and the slag burden, there is a stimulus towards removing this impurity by pretreatment. Co-operative investigations have demonstrated the possibility of so doing and, provided that the additions of lime and iron oxide are correctly chosen and the oxygen fed correctly with respect to the slag/metal interface, it is possible to remove substantially all the silicon and phosphorus while still leaving enough carbon for good working of the heat. For example, a hot metal containing 4% C, 0·7% Si, and 0·7% P can be converted to one containing 1·5% C and 0·05% P.

There are also indirect production advantages in the use of prerefined metal, particularly for low-carbon steels, in that yield can be higher. Pre-refining slags can be produced with low iron-oxide contents, even when ore is used, so that there is little loss in this way. Although high slag iron-oxide contents are unavoidable when the steel is finished, the reduced amount of slag reduces this source of loss.

It is therefore clear that the use of pre-refined metal can add substantially to the output rates of open-hearth furnaces. Much still remains to be done to develop better techniques and to devise refining vessels to cope with melting-shop requirements and to enable slags to be recovered more conveniently when these have an economic value. The fume problems associated with the use of oxygen also require solution and the possibility of employing steam as a local cooling agent is showing signs of promise.

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The Mallock Cone Hardness Test and its Relation to Indentation Methods

By G. H. H. Williams, Ph.D., B.Sc., and H. O'Neill, D.Sc., M.Met.

SYNOPSIS

The practical aspects of the Mallock test have been studied for annealed and quenched steels and other metals when initially in the non-work-hardened state. The Mallock hardness under these conditions depends upon the included angle of the conical test-piece and is greatest for cones from 60° to 90°, with a maximum at about 67°. The distribution of strain-hardening within some test-pieces has been explored. Just below the surface of the deformation flat in 67° cones the strain-hardening reaches a maximum value which approximately equals the Vickers hardness produced in the same metal by the heaviest cold-rolling or compression. This maximum hardness is twice the 67° Mallock hardness and methods for its determination are described. Comparisons have been made with the results of lubricated cone, ball, and pyramid tests. 1463

Introduction

MEASUREMENT OF THE DEFORMATION of a specially shaped test-piece when pressed against some other surface was used as a hardness test by Hertz, Auerbach, and others. In 1926 Mallock[1] briefly described a procedure by which an extremely small pointed conical specimen was slowly pressed by load L against a sapphire plate, and the diameter d of the resulting flat was measured. The basal diameter D_M of the original Mallock cone appears to have been only about 0·005 in. and our measurement of its included angle is 105°, so that very small specimens could be examined in this simple way. For cones of annealed and quenched steel, Mallock used test loads ranging from about 0·5 to 5 kg, and found that $L \propto d^2$, so that the Mallock hardness $P_{MK} = 4L/\pi d^2$ was practically independent of load. Ideally the procedure observes the principle of geometrical similarity of deformation for a given angle of cone.

This test is not well known but it could obviously be used at high temperatures[2] and dynamic loading conditions,[2] and for creep experiments.[3] In some metals the edges of the flat develop cracks as deformation proceeds, and this might indicate hot or cold working behaviour.[16] In the present paper the characteristics of relatively large test-pieces have been examined as part of practical studies of plastic deformation. Comparisons have been made with Brinell, Ludwik, and Vickers indentation methods to judge the practical utility of the test.

Manuscript received 11th July, 1957.

Dr. O'Neill is Professor of Metallurgy at University College, Swansea, and Dr. Williams is a Technical Officer, I.C.I. Metals Division, Swansea.

PREPARATION AND TESTING OF SPECIMENS

Some of the wrought materials used for the cones were employed in an earlier hardness paper,[4] and particulars are given in Table I, together with the temperatures for annealing *in vacuo* (1 h) after machining. Cones of ¼–1-in. dia. base were used because of ease of manipulation, and heavy deformations were produced to simplify measurements of the flats.

A cylindrical base was generally left on each cone, and the height of this portion varied with circumstances. In this test there will be some value of 'deformation ratio' d/D_M above which the basal reaction of the metal will be affected, and this has been studied.

Loading was by a small hardened steel die mounted between the compression platens of a 5-ton Amsler pendulum machine. For lubrication, liquid paraffin B.P. was freshly applied to all contact surfaces at each increment of load. The areas of the flats were determined from the average of two diameters at right-angles measured with an Amsler travelling Brinell

Table I
PARTICULARS OF WROUGHT MATERIALS USED FOR CONES

Specimen	Composition, %	Form	Heat Treatment, °C	Final Grain Dia., mm	Vickers Hardness
Al *1*	99·5	2-in. round bar	A. 450	Fine	22
Al *2*	99·5	Diamond section billet	A. 450	Coarse (columnar macrostructure)	20
Cu *1*	H.C. 99·93	3-in. dia. billet	A. 500		42
Cu *2*	H.C. 99·96	1-in. dia. rod	A. 487	0·059	42·2 n = 2·48
		½ in. dia. rod	A. 487	0·056	42·6 n = 2·63
		¼-in. dia. rod	A. 487	0·042	41·0 n = 2·42
Armco		1-in. dia. rod	A. 950	...	92
Steel *11*	C 0·105 Mn 0·47		A. 900	...	
Steel *22*	C 0·22 Mn 0·55	2½-in. dia. billet	A. 900	...	149
Steel *93*	C 0·93 Mn 0·63	1-in. dia. rod	A. 850	...	263
Mn steel	C 1·25 Mn 12·8	⅜-in. bar	W.Q. 1050	...	232

microscope. The flats were generally circular, except in some tests with metal Al *2* which showed bulges. In this case areas were measured from photographs of the irregular flats. The sides of the cones generally remained straight, but as the included angle was decreased below 90° with soft copper there was a progressive tendency for bulging immediately below the flat. The formation of a lip below the flat or bulging on the flanks would presumably follow the principles governing 'piling-up' and 'sinking-in' in indentation tests.

This point was confirmed by measurements made to determine the relation between the decrease in height of cones by deformation and the actual diameter of the flats produced. As a practical test one might use a Rockwell-type machine and measure decrease in height rather than flat diameter, provided that the actual relation between the two did not depart greatly from the geometrical relation. Results for 90° cones of several metals are plotted in Fig. 1 and it will be seen that annealed steels and aluminium gave flats of greater diameter for a given decrease in height than soft copper and manganese steel. Presumably this is because the former give a piling-up lip while the latter give a sinking-in bulge.

DURATION OF LOADING AND REPEATED LOADING

It is known that soft metals, and in particular copper, show flow effects during static indentation tests, and several minutes may be required for equilibrium. There is not much hope for a practical test if loading must be maintained for more than 15 s. As the latter value has been standardized in most countries, results for this period have been obtained in the present work. Logarithmic plots of L against d for Cu *2* gave an index which was always slightly less than 2·0.

Tests were made with 90° cones of metal Cu *2* to find whether repeated-increment loading of constant duration on the same specimen gave the same result as single applications of greater loads on new specimens. Over a loading range of 102–762 kg no difference was found, so for studying the effect of load the same specimens have been repeatedly used with increments of load. For soft white metals Kenneford and O'Neill[5] found that repeated-increment loading of 30 s gave lower Mallock values than separate loading.

EFFECT OF LUBRICATION

Cones of three different included angles were machined from 1-in. lengths of 1-in. dia. rod of metal Cu *1*, the cylindrical bases of the three sets thus being of different heights. New cones were used for each testing load with paraffin lubrication, but one cone of each series was compressed in the dry condition. Results obtained are given in Table II.

It is evident that lubrication has only caused a fall

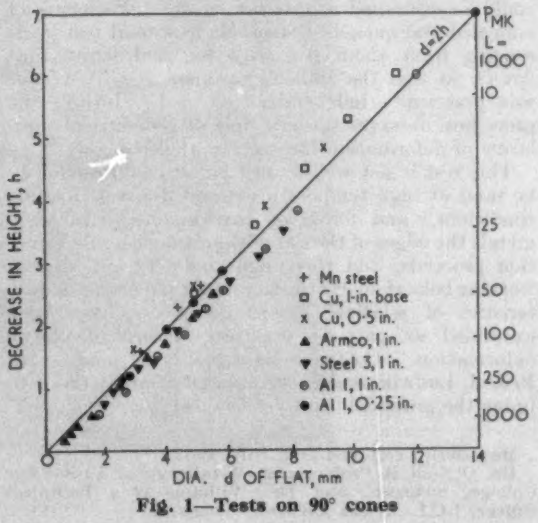

Fig. 1—Tests on 90° cones

Table II

EFFECT OF LUBRICATION ON SPECIMEN Cu *1*

Cone Angle	Load, kg	Mallock Hardness, kg/mm²		Deformation Ratio, d/D_M
		Dry	Lubricated	
60°	1244	...	55·2	0·21
	4584	55·3	54·8	0·41
90°	1224	...	54·9	0·21
	4577	53·7	52·8	0·41
120°	1224	...	49·2	0·21
	4580	46·4	45·9	0·44

in hardness value of about 1%, confirming the findings of Mallock,[1] after determining coefficients of friction, that lubrication has no practical effect under these conditions. In the subsequent tests lubrication was nevertheless always employed.

In Table II increase of cone angle above 60° has given a fall of hardness number, and trebling of the heavy load on each lubricated copper cone produced the same effect. The latter observation differs from Mallock's experience with relatively light loads on steel reported above, and is one of the peculiarities of copper.

EFFECT OF LOAD ON DEFORMATION OF BASE OF 90° CONES

Cones of 90° angle and bases of $\frac{1}{4}$, $\frac{1}{2}$, and 1 in. dia. with a cylindrical portion were made from metals Al *1*, Armco, and steel *22* and tested at increasing loads. The basal diameter was also measured after each loading, and the Mallock hardness calculated. The results are given in Fig. 2 on a basis of d/D_M (where D_M = original base diameter) and the value of the ratio at which the base was just beginning to enlarge is indicated by an arrow. Results for Cu *2* are included though measurements of the base were not made in this series.

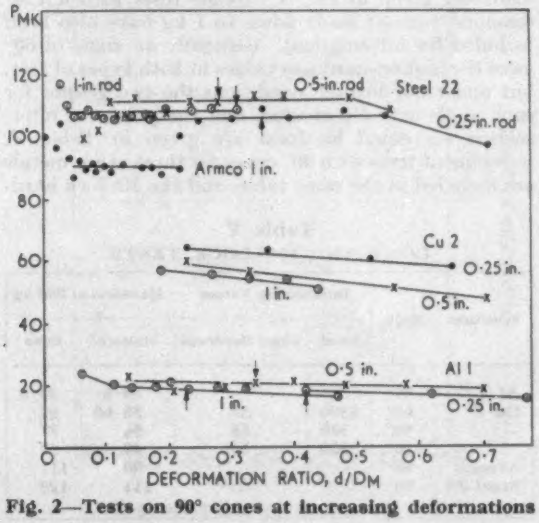

Fig. 2—Tests on 90° cones at increasing deformations

Table III

EFFECT OF LOAD ON DEFORMATION OF 90° CONES OF Mn STEEL

Load, kg	Mallock Hardness		Deformation Ratio, d/D_M	
	Specimen 1	Specimen 2		
200	...	232	0·08	
500	232	250	0·13	
1000	257	268	0·17	
1500	275	...	0·21	
2000	265	270	0·24	Base dia. increased
4000	...	282	0·34	
5000	...	278	0·38	

It appears that flow of the base has occurred for 90° cones after reaching $d/D_M = 0·3$ approx. The hardness results for different loads are fairly constant when the deformation ratio falls between 0·1 and 0·4, and 0·2 seems a desirable value to aim at. Of the four metals plotted in Fig. 2, copper seems most prone to a fall of hardness with increase of load. Its increase of Mallock hardness with decrease of base diameter is due to the original progressive variation in crystal size of the three different test-pieces employed (*see* Table I).

Manganese steel cones of 0·5 in. base and 0·25 in. height (90°) gave the results in Table III.

The hardness is fairly steady and averages 273 after 1000 kg has been passed. The deformed cones had curved flanks, as would be expected for this steel.

'ELASTIC' OR ABSOLUTE MALLOCK HARDNESS

To determine the mean hardness stress free from strain-hardening effects, experiments were made on three metals by (*a*) the pre-machining principle of Mahin and Foss,[13] and (*b*) the Hanriot method[14] of repeated loadings, annealings, and microscopic measurement of the indentation. In the former case flats of appropriate size were machined on 90° Mallock cones which were then annealed to remove machining effects. Each conical frustum was loaded on an Amsler hydraulic tester and its height measured with a micrometer after each load increment. The latter is not a sensitive measurement for this purpose and flow limits recorded in Table IV are only approximate.

The results of ball, cone, and Mallock tests made by the method of repeated annealings are given in Table IV. The initial load chosen for the ball gave an angle of indentation of about 90° and the other impressions and flats were between 3·5 and 4·0 mm dia. so as to obtain results which should be roughly comparable.

The values for the annealed Mallock tests and the machined frustum are generally lower than the others, and incidentally Krupkowski's previous ball tests on copper using the annealing method gave somewhat lower values from those of Mahin and Foss using machining. The low results for the Mallock test are presumably due to reduced support by surrounding metal, as will be discussed later.

EFFECT OF CONE ANGLE

Specimens of six different included angles with a cylindrical base $\frac{1}{8}$ in. high (i.e. the cones were not of

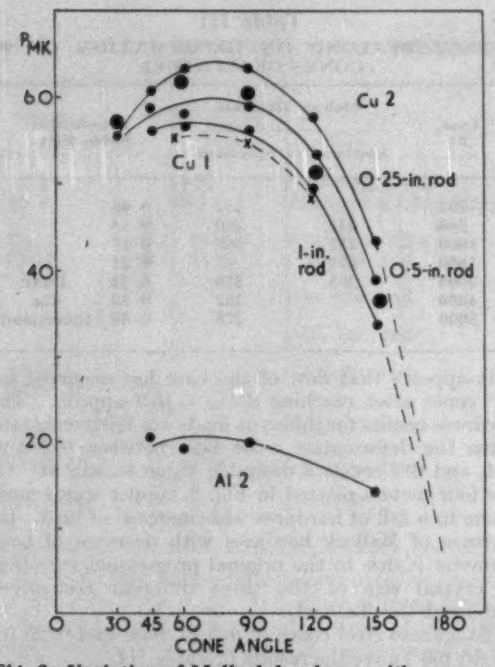

Fig. 3—Variation of Mallock hardness with cone angle (Krupkowski's cone indentation results are shown thus ●)

the same height) were machined from $\frac{1}{4}$, $\frac{1}{2}$, and 1-in. rod of Cu *2*. They were each tested under a wide range of loads giving d/D_M values up to 0·87, but only interpolated results of P_M for $d/D_M \simeq 0{\cdot}25$ have been plotted in Fig. 3. Values obtained for Cu *1* and Cu *2*, with 1-in. dia. bases in both cases but varying heights in the latter, suggest that constant heights are not required for studying the effect of included angle. The Mallock hardness for Cu *2* again increased as the specimens became smaller, probably owing to grain size effects as mentioned earlier.

The results indicated that the Mallock hardness of copper (*a*) depends upon the cone angle (as would be expected) and is a maximum at 60–90°; (*b*) decreases slightly (15-s loading) as the load was increased to give higher values of d/D_M; (*c*) showed a minimum variation (7%) with a range of loads when a 45° cone is used.

It is probable that the graphs are converging to zero hardness as the 0° cone angle is approached, and also towards the elastic hardness value as 180° is approached.

Table IV

'ELASTIC' HARDNESS (LUBRICATED), kg/mm²

Specimen	Repeated Annealings			90° Mallock Frustum Flow Limit
	5-mm Ball Indenter	90° Cone Indenter	90° Mallock Cone Test	
Cu *2*	10·5	10·3	8·3	6
Steel *11*	31·1	31·1	24·8	25
Steel *93*	44·0	46·3	34·7	60 (?)

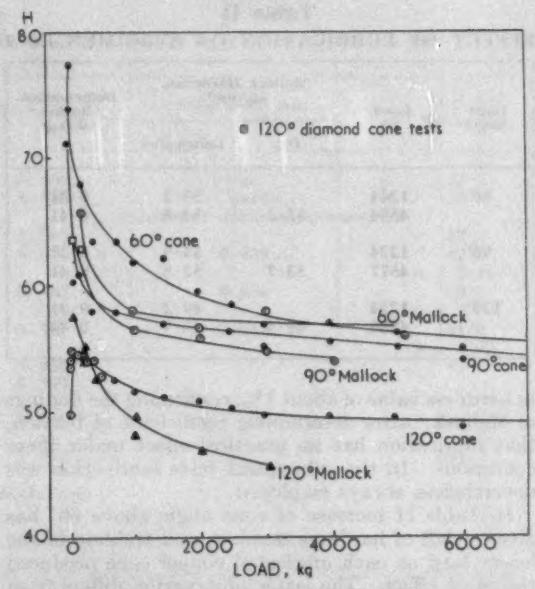

Fig. 4—Cone indentation and Mallock tests on copper *2*

RELATION BETWEEN MALLOCK AND CONE HARDNESS VALUES

Krupkowski[6] has published cone hardness tests at increasing loads on copper using indenting tools of angles ranging from 30–150°. His results for a given cone indenter decreased considerably at first for loads up to 750 kg, but then decreased only slightly with increase of load. His hardness values at 1000 kg have been included in Fig. 3 and show reasonable agreement with those of the present tests for Mallock cones of angles directly equal to those of Krupkowski's indenters, and give a maximum at about 60°.

Further studies of this possible relation were made, and Mallock values and mean pressure cone hardnesses (P_C) on Cu *2* for three cone angles and various loads are given in Fig. 4. (Some tests with a 120° diamond cone at loads down to 1 kg have also been included for information). Generally an angle of 60° gave the highest hardness values in both types of test, but under our loading conditions the two graphs for each angle actually crossed, and the points of intersection for equal hardness are given in Table V. Subsequent tests with 90° cones for three other metals are included in the same table, and the Mallock hard-

Table V

CONE AND MALLOCK TESTS

Specimen	Angle	Intersection Values		Hardness at 1000 kg	
		Load	Equal Hardness	Mallock	Cone
Al *1*	90°	...	...	19·5	22·5
Cu *2*	60°	3500	57	58–60	62
	90°	500	58	56	57
	120°	300	54	49	52
Armco	90°	...	...	90	111
Steel *22*	90°	...	...	111	128

Fig. 5—' Partial supporting mass '

ness at 1000 kg (and it varies with load for copper) was slightly lower than the cone hardness. In the range examined it may be concluded that a given Mallock angle yields roughly the same result as a mean pressure cone test of the same included indenter angle, but the Mallock values are about 15% lower.

In the Mallock test the cone apex is compressed into a strain-hardened plug forming under the flat, which simultaneously acts as an indenter. The amount of resistance offered by the metal around it will depend upon the inclination of the sides of the cone. What the present authors have called the ' partial supporting mass ' of the test piece will perform as an extending ring. If the plug is considered as a right-angled cone, then the annular zone normal to its surface and extending to the boundaries of the test-piece will be particularly involved in the resistance to deformation. In Fig. 5 the zone for a 60° and 90° cone when $d/D_M = 0{\cdot}20$ is sketched and shaded-in, and it will be seen that these two cone angles cover a range where the partial supporting mass runs out from the flanks of the cone to a position along the base. It is believed that a critical condition would arise with increasing cone angle when the zone just reached the support of the base. The geometry of this condition involves a cone angle of about 67° and the authors consider that maximum hardness values in lubricated Mallock and Ludwik tests will be obtained with this angle. In both tests a cone angle of 180° gives the equivalent of a compression test. The volume of the partial supporting mass was measured, and when plotted against cone angle the graph rises through a maximum at about 67°.

MALLOCK HARDNESS AND BALL HARDNESS VALUES

Considering next the ball test, it is well known for annealed metals that the hardness value (mean pressure P_m) increases continuously with load and angle of indentation ϕ ($\sin \phi/2 = d/D$). Since we have seen that cone hardness values pass through a maximum with increasing angles of indentation, there cannot be a simple continuous relation between cone

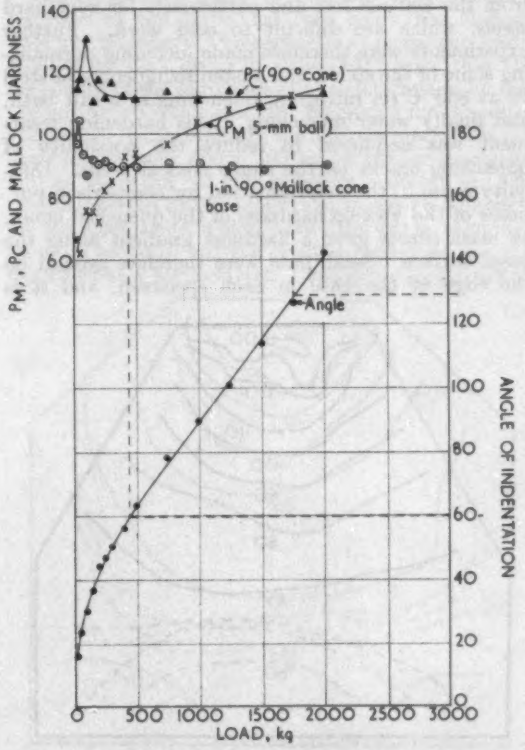
P_M, P_C AND MALLOCK HARDNESS
ANGLE OF INDENTATION
LOAD, kg
P_C (90° cone)
(P_M 5-mm ball)
1-in. 90° Mallock cone base
Angle
0 500 1000 1500 2000 2500 3000
140 120 100 80 60
180 160 140 120 100 80 60 40 20 0

Fig. 6—Tests on Armco

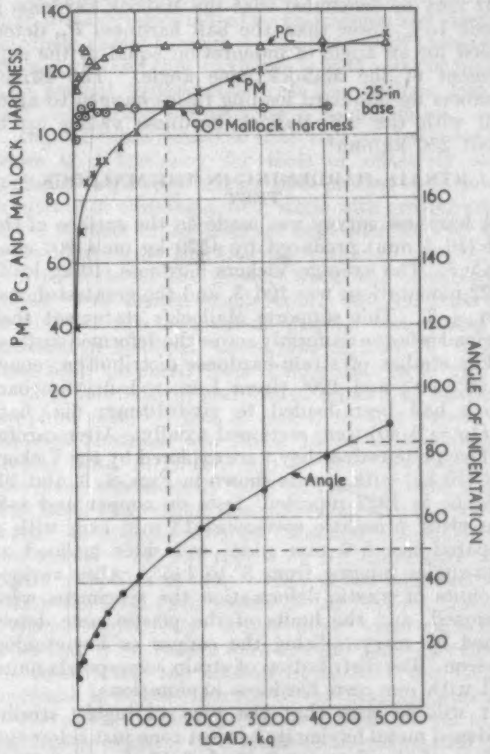

Fig. 7—Tests on steel *22*

Table VI

BALL AND MALLOCK TESTS

Specimen	Mallock Cone Angle, a	Equivalent Ball Test Angle of Indentation	Supplement to Mallock Angle $\phi = (180° - a)$	Ball Hardness, P_m, for ϕ	Standard Brinell No., H_B	Mallock Hardness, P_{MK}
Al *1*	90°	50°	90°	22·5	19·2*	19·5
Cu *2*	45°	92°	135°	64	...	56
	60°	100°	120°	62	...	57·5
	90°	90°	90°	56	40*	56
	120°	65°	60°	47	...	49
	150°	42°	30°	35	40*	41
Armco	90°	60°	90°	102	86†	90
Steel *22*	90°	50°	90°	131	110†	111
„ *93*	90°	...	...	...	269†	251

* $L/D^2 = 5$ † $L/D^2 = 30$

values and ball values. Ball test curves for P_m and ϕ were determined at 15-s loading under lubricated conditions for the metals being studied, and were plotted against load as shown, e.g. in Figs. 6 and 7. It will be seen for Armco that the 90° Mallock hardness and the P_m curve intersect at 90 kg/mm², and by interpolation this represents a 60° ball angle of indentation as determined conventionally. Equivalent indentation angles have been read off from similar graphs and are given in Table VI. It will be seen that they correspond approximately with the supplement to the Mallock cone angle. The ball hardness value for this supplement has then been interpolated, and is given, together with the standard Brinell number H_B, in Table VI.

It may be concluded that the Mallock hardness is about 15% lower than the ball hardness P_m determined for an angle of indentation equal to the supplement of the Mallock cone angle. The Brinell numbers for standard loading ratios happen to agree well with the 90° Mallock hardness values up to about 250 kg/mm².

STRAIN-HARDENING IN THE MALLOCK TEST

A hardness survey was made on the surface of the flat (10·5 mm) produced by 4570 kg on a 90° cone of Cu *1*. The average Vickers hardness (10-kg load) of 22 indentations was 106·3, and the greatest deviation ± 3. This supports Mallock's statement that the load is borne uniformly across the deformed surface.

For studies of strain-hardness distribution, cones of 60°, 90°, and 120° (from 1 in. × 1 in. dia. bar) which had been loaded to give 10-mm dia. flats ($d/D_M = 0·40$) were sectioned axially. After careful surface preparation they were explored by the Vickers test (10 kg) with results shown in Figs. 8, 9, and 10.

Sachs in 1927 reported[7] tests on copper and soft iron using prismatic specimens 15 mm long with a prepared flat 5·6 mm wide, and sides inclined at semi-angles ranging from 5° to 145°. After various amounts of plastic deformation the specimens were sectioned, and the limits of the plastic zone determined by recrystallizing the copper or Fry-etching the iron. The distribution of strain corresponds quite well with our own hardness explorations.

It will be seen that the plug of highly strain-hardened metal having its hardest zone just below the surface of the flats (at 0·10 d, 0·17 d, and 0·20 d respectively) has been pushed into the body of the specimen. These three cones have been compressed further than is desirable, but it is clear that in the 60° cone the lines of equal hardness are relatively flat and run outwards towards the flanks, while in the 90° and 120° specimens they bend towards the edges of the flats. The changeover presumably occurs at a 67° cone angle. The same effects were previously observed by the present authors below cone tool indentations, with maximum Vickers values of 125, 120, and 113 respectively (ref. 4, Figs. 3, 4, and 5). The value for the 60° cone was considered to be about the greatest hardness obtainable for this metal, i.e. its 'pressure of fluidity' p.

It would be interesting to try to secure this value from the Mallock test and particularly for very hard steels, which are difficult to cold work. Further experiments were therefore made including normalizing some of the steels, and austenitizing cones of steel *93* at 850° C (in nitrogen), quenching in a salt bath, and finally water quenching. This hardening treatment was employed to reduce the possibility of quenching cracks on the sharp conical point. Difficulty arose in the determination for comparison purposes of the Vickers hardness of the quenched cones, as mass effects gave a hardness gradient along the basal surface. Small flats were therefore ground on the edge of the base in each specimen, and it is

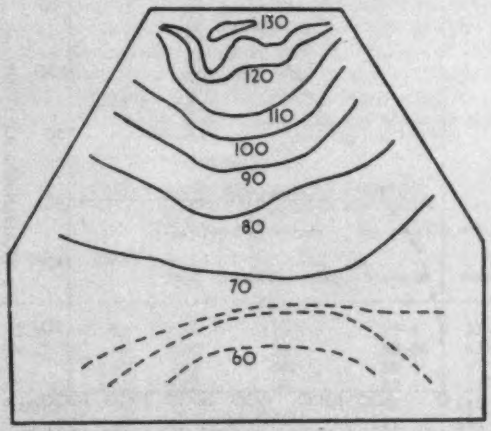

Fig. 8—Strain-hardening in sectioned 60° cone—copper *2*

Table VII

TESTS ON CONES OF STEEL *93* (12-mm base)

Reference	Heat Treatment from 850° C	Cone Angle	Load, kg	Mallock Hardness	Vickers Hardness (30 kg)
...	Normalized	67°	300	230	270
...	Q. 245°—15 min W.Q.	67°	1000	593	695
A			2000	620 (crack)	
...			3000	635 (crack)	
B	Q. 160°—1 min W.Q.	67°	1000	670 (crack)	785
...		120°	100	880	893
...			200	860 (craze)	
C			300	850 (crack)	
...	Q. 160°—1 min W.Q.	67°	50	465 (?)	
...			100	700	842
...			150	760	
...			200	775	
D			250	750 (crack/flat)	
...	Q. 160°—1 min W.Q.*	67°	50	700	
...			100	710	
E			150	685 (crack/flat)	

* 6-mm base cone

suggested that tests on these represent approximately the Vickers hardness of the apex. Results obtained using a sintered carbide pressure plate and graphitic lubricant are given in Table VII. Where cracking occurred during testing it was first observed across the flat, and under greater loads as a few straight lines down the flanks, while in reference *B* (col. 1) the flat showed a completely circular fissure from which radial cracks ran off down the flanks. A test load of 100 kg seems suitable for the hardened cones.

Attempts were made to evaluate the maximum hardness of the embedded core below the Mallock flats by ' concentric ' Vickers tests at increasing loads. Results for Cu *2* given in Table VIII show that the maximum of the hard zone can be determined by this ' progressive Vickers loading ' technique for the softer specimens. Unfortunately the Vickers machine is not designed to work above 100 kg on harder specimens and for these did not give sufficient penetration. The results reported by Niconoff[8] refer to repeated impacts on Mn steel cones which were afterwards examined on axial sections, but the original procedure was not described as a Mallock test. Consequently, for metals

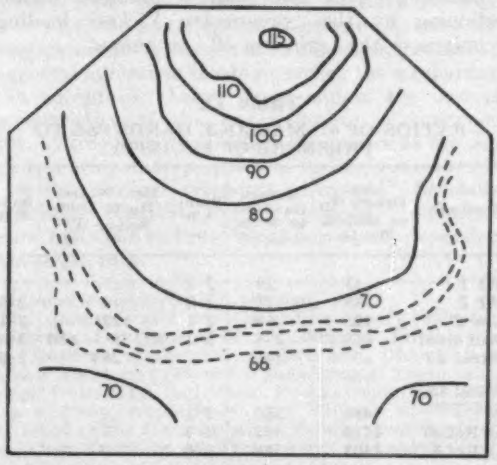

Fig. 9—Strain-hardening in sectioned 90° cone—copper *2*

originally over about 200 Vickers a ' grinding off ' technique may be used by which a layer of 0·2 *d* depth is removed from the Mallock flat, and a Vickers test at 10 kg is made on the new surface. This procedure gave the results *D* and *E* in Table VIII, the value of 1402 kg/mm² being the highest observed for steel by the present authors.

DISCUSSION OF RESULTS

Studies of cone and pyramid tests have shown that with *well-lubricated* indenters the indentation stress or hardness passes through a maximum with increase of apex angle, and this maximum is in the 60–90° region. The present experiments with the Mallock test on non-cold-worked metals show a similar effect.

Dugdale[11] has remarked that with pointed indenters there is a tendency for tools of relatively small included angle to penetrate by a process approaching a cutting or cleaving action, while with greater angles there is more of an internal expansion effect. Ball tests do not show this cleaving action.

After most of the present work was completed a paper[12] was noticed which reports tests on brass and hard steel (for instrument pivots), but makes no mention of Mallock. Cones ranging from 30° to 120° had been prepared from 2-mm dia. steel wire (C 0·93%, Mn 0·10%) and loaded up to 2 kg against a sapphire disc. What is called, in this paper, the Mallock hardness was found to be independent of testing load (0·25–2·0 kg) for 50–120° cones, but increased continuously with increase of cone angle. The latter observation does not agree with the present work. It appears that the ' deformation ratio ' did not exceed 0·02, and results for 90° cones were compared with Vickers tests. Thus in the annealed condition the steel gave values of 152 Mallock and 163 Vickers respectively, whilst after water-quenching from 750° C the results were 906 and 935 respectively. At these levels the authors agree that the Vickers hardness is higher than the 60–90° Mallock hardness.

The simple Mallock test does not enable the work-hardening capacity of a metal to be determined, but tests with cones of different angles might give a clue

Table VIII
VICKERS TESTS ON MALLOCK FLATS

Specimen	Mallock Angle	Mallock Hardness P_{MK}	Vickers Hardness at Progressive Testing Loads								
			2·5 kg	5 kg	10 kg	20 kg	30 kg	50 kg	70 kg	100 kg	Max. on Axial Section
Al *1*	90°	20	38	42	*43*	41	...	...	...	...	...
Al *2*	67°	22	*45*	42	41	...	...	...	...	...	45*
Cu *2*	60°	60	...	...	118	...	119	117	125	...	130
	90°	56	...	...	106	...	108	109	*117*	108	115
Steel *22*	120°	49	...	...	101	...	98	99	*111*	109	110
Mn steel	67°	141	...	...	...	...	...	241	243	245	289*
	60°	...	...	...	...	...	...	520†	...	...	600‡
	90°	270	...	...	508	...	520	509	...	533	...
	90°§	275	...	447	514	*618*	490	...	...	...	...
Steel 93 *N*	67°	230	...	...	...	...	...	336	339	486	...
Q. Ref. *A*	67°	593	...	...	...	672	...	753	770	*1110*	...
Q. Ref. *C*	120°	880	...	...	...	884	897	946	994	1110	...
Q. Ref. *D*	67°§	775	...	...	1332	...	...	...	...	...	...
Q. Ref. *E*	67°§	710	...	1145	*1402*	1028	...	...	...	...	...

* Test on cylinder, cold-compressed 88%
† Converted Niconoff result: Rockwell C51
‡ Niconoff: Rockwell C55. cf. also Stead's tensile limit $P_a = 630$
§ 'Grinding off' technique

to this property. If so, it might follow that Mallock tests on a strain-hardened metal would show less variation of hardness with cone angle than that found on the present unstrained specimens.

The following generalizations arise from all the available results including some from an earlier paper by the present authors[4]:

Punching stress of cold-worked copper	= 187kg/mm²	(Bishop, Hill, Mott[18])
Vickers H_D max. annealed copper	= 132	'Pressure of fluidity'[4]
Vickers H_D max. compressed copper	= 133	'Pressure of fluidity'[4]
Vickers H_D max. on 60° cone indent	= 125	'Pressure of fluidity'[4]
Vickers H_D max. on 180° ball indent	= 125	'Pressure of fluidity'[4]
Vickers H_D max. below Mallock flat	= 125	'Pressure of fluidity'[4]

It therefore appears from Table IX that

67° Mallock hardness × 2 = Pressure of fluidity.

This latter is also the hardness value of the hardest zone in the strain-hardened plug below the 67° Mallock flat.

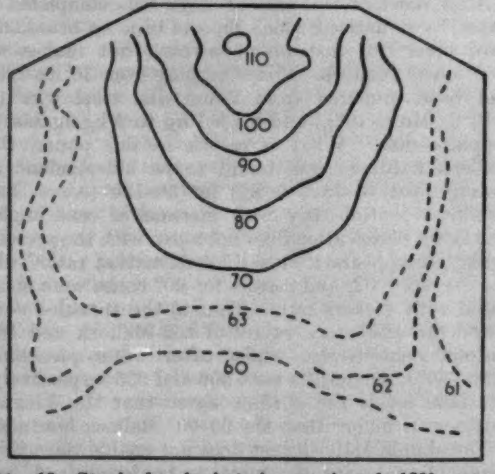

Fig. 10—Strain-hardening in sectioned 120° cone—copper *2*

CONCLUSIONS

(1) For small specimens (e.g. 0·005-in. dia. wire) and when a microtester is not available, the Mallock cone test provides a simple method of obtaining hardness values and indications of workability. Large cones up to 1-in. base dia. and small cones of hard steel have been examined.

(2) Provided that the ratio of deformed flat d to base dia. D_M falls between 0·05–0·3, the results obtained for a given cone angle are independent of testing load. Copper and white metals show a decrease of hardness with increase of load. The lower limit of the deformation ratio is desirable for testing hard steels.

(3) For a given unstrained metal the Mallock hardness depends upon the cone angle. It is greatest for angles of 60–90° with probably a maximum at 67°.

(4) Exploration of sectioned Mallock test pieces of copper showed that the maximum Vickers hardness of the strain-hardened plug, at about 0·2 d below the flat in the 60° cone, represents the maximum hardness which the metal can reach by cold working (pressure of fluidity). This value can be obtained without sectioning by the 'progressive Vickers loading' technique or the 'grinding off' technique.

Table IX
RATIOS OF 67° MALLOCK HARDNESS TO PRESSURE OF FLUIDITY

Specimen	Max. Vickers H_D on Mallock Flat (A)	Mallock Hardness 60°/90° (B)	Ratio A/B	Max. Vickers H_D by Cold Rolling (C)	Ratio C/B
Al *1*	43	20	2·1	...	...
Al *2*	45	23	2·0	46[10]	2·0
Cu *2*	125	60	2·1	127[4]	2·1
Mn steel	618	275	2·2	RC 58[9] = 650	2·4
Steel *22*	...	141	...	289	2·0
Steel *93* N	486	230	2·1	...	...
Q. Ref. *A*	1110	593	2·0	...	...
Q. Ref. *E*	1402	710	2·0	...	...

(5) The Mallock hardness for a 67° cone multiplied by 2 is found to be equal to the pressure of fluidity. A factor higher than 2 was observed for Mn steel.

(6) The Mallock test is comparable with the lubricated cone indenter test, but for any given angle its results are about 15% lower. The 67° Mallock test results are somewhat lower than the standard diamond pyramid values.

(7) For a given Mallock cone the (lubricated) mean pressure ball hardness for the supplement to the cone angle is somewhat greater than the Mallock hardness.

Acknowledgements

The copper and aluminium used in this work was kindly presented by Imperial Chemical Industries, Ltd., through Dr. Maurice Cook. The manganese steel cones were kindly provided by Mr. E. W. Colbeck of Hadfields, Ltd., and Mr. E. Petty, B.Sc., carried out the quenching of the hard steel cones. Mr. A. H. Moffat assisted with specimens and apparatus in various ways.

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A New Concept of Hydrogen Embrittlement in Steel

By J. G. Morlet, H. H. Johnson, and A. R. Troiano

SYNOPSIS

Current theories of hydrogen embrittlement have been critically evaluated from an investigation of the influence of plastic strain on the ageing characteristics of hydrogenated steel. The recovery curve is strongly modified by plastic deformation subsequent to hydrogenation.

The planar pressure theory and the surface adsorption theory are both incapable of explaining the observed results. The postulate that hydrogen exerts a maximum embrittling effect in the region of most severe triaxial stress-state does yield a consistent interpretation of the data.

Embrittlement results from hydrogen in solution; the hydrogen contained in internal voids is non-damaging. 1466

Introduction

THIS INVESTIGATION was undertaken in an effort to provide a clearer picture of the mechanism whereby hydrogen reduces the ductility of steel. To be sure, the metallurgical literature reports many investigations of hydrogen embrittlement; yet, today, no general agreement exists regarding the mechanism.

An acceptable theory must explain the unusual characteristics of the embrittlement phenomenon. First, hydrogen embrittlement disappears at low and high test temperatures and is accordingly most severe in an intermediate temperature range.[1] Secondly, in striking contrast to 'conventional' embrittlements, hydrogen embrittlement is inversely dependent upon strain rate.

Manuscript received 7th October, 1957.

Dr. Johnson and Mr. Morlet, formerly Research Assistants, Department of Metallurgical Engineering, Case Institute of Technology, Cleveland, Ohio, U.S.A., are now Assistant Professor of Metallurgical Engineering, Lehigh University, Bethlehem, Pennsylvania, and in the French Army, respectively. Dr. Troiano is Professor and Head of the Department of Metallurgical Engineering, Case Institute of Technology, Cleveland, Ohio, U.S.A.

Historically, the planar pressure theory advanced by Zapffe *et al.* was first used to explain these experimental observations.[2] They postulated that molecular hydrogen can precipitate into internal 'voids' in the lattice structure and therein build up pressure sufficient to cause premature fracture. Upon straining, the voids enlarge and the hydrogen pressure drops. Further precipitation of hydrogen is necessary to maintain a damaging pressure. If the rate of straining is greater than the restoration of P_{H_2}, embrittlement should decrease. A similar effect may

Table I
COMPOSITION OF 4340 STEEL

C	Mn	Si	Ni	Cr	Mo
0·402%	0·82%	0·29%	1·72%	0·85%	0·25%
P	**S**	**H**	**O**		**N**
0·012%	0·015%	0·00013%	0·003%		0·009%

be expected from lowering the test temperature since the gas pressure and the rate of delivery to the voids decrease with the temperature.

A completely divergent theory has been developed by Petch and Stables,[3, 4] who suggest that fracture arises from the formation of a crack ahead of an array of dislocations piled up against a grain boundary. Because of adsorption of hydrogen on the surface of the crack as it forms, the stress required for fracture is lowered.

The influence of strain rate is explained on the basis that the adsorption atoms are supplied from hydrogen in solution: "The extension of a crack under stress will take place in steps which occur when hydrogen solute atoms arrive at its edge in the course of diffusion." Since the proposed embrittling mechanism is diffusion-controlled, the apparent embrittlement should decrease at high strain rates where there is insufficient time for appreciable hydrogen diffusion to the crack edge, and at low temperatures where the hydrogen diffusion rate is low.

Other proposed mechanisms of hydrogen embrittlement are, broadly speaking, variations of the planar pressure theory. For example, the refinement introduced by Bastien and Azou[5] lies primarily in the mechanism whereby hydrogen is delivered to the voids. It is suggested that hydrogen is concentrated around dislocations as a Cottrell atmosphere. Under strain, the dislocations travel through the lattice. Whenever hydrogen-laden dislocations reach a void, it is presumed that a certain amount of hydrogen is discharged into the void, thus increasing the pressure and causing embrittlement.

Another variation of the pressure theory has been presented by de Kazinczy.[6] In his viewpoint, the contribution of the hydrogen gas in the void to the energy necessary for crack propagation arises from the expansion of the gas during crack growth. This mechanism is based on the thermodynamic concept that expansion of a gas is accompanied by a release of energy. Thus, expansion of the hydrogen gas during crack growth releases energy and thereby lowers the applied stress necessary for crack propagation.

Further crack growth depends on a subsequent increase in energy content of the gas in the crack. This will occur when hydrogen diffuses from the lattice to the crack and precipitates therein. Thus, the embrittlement is diffusion-controlled and would tend to disappear at high strain rates and low temperatures.

These theories exhibit similar features, although

Table II
DUCTILITIES FOR VARIOUS CHARGING AND TESTING CONDITIONS

Condition	Ductility, % R.A.
Uncharged specimen tested at room temperature	40
Specimen charged and cadmium-plated, tested at room temperature	5
Specimen charged and cadmium-plated, baked 1 h at 300° F, tested at room temperature	10
Uncharged specimen tested at — 321° F	22
Specimen charged and cadmium-plated, baked 1 h at 300° F, tested at — 321° F	22

the proposed mechanisms are different. All investigators postulate a lattice involving defects. Depending on the author, these defects may be termed voids, lattice rifts, Griffith cracks, or piled-up dislocations producing cracks. The implicit assumption is made that the voids, as they will be termed in this report, are of large size when compared with the volume of the lattice unit cell. The damaging hydrogen is assumed to be localized in voids or at the void surface. This localization of the hydrogen concentration appears necessary, since embrittlement is observed at very low hydrogen contents.

The specific details of the embrittlement mechanism depend upon whether the hydrogen at the void surface or in the void is assumed to be embrittling. Zapffe, Bastien and Azou, and de Kazinczy assume that hydrogen in voids is damaging, whereas Petch and Stables believe that embrittlement is caused by hydrogen adsorbed on the void or crack surface.

On this basis, the severity of hydrogen embrittlement is related to the hydrogen pressure in a void and the hydrogen concentration in the lattice around the void. These quantities are not independent, since, in a hydrogenated steel, a unique steady-state distribution will be established between hydrogen pressure in the voids and lattice hydrogen concentation. The magnitude of the observed embrittlement will be dependent upon the steady-state distribution, since it fixes the void pressure and the lattice concentration.

A change in the steady-state distribution should then produce a change in the degree of embrittlement, and perhaps permit a critical evaluation of the various theories. For a given hydrogen content and specimen size, the distribution will be determined primarily by the volume of the voids. The steady-state distribution may be varied by plastic deformation of the steel either before or after charging. The deformation is presumed to change the size and the number of voids or cracks. This report explores the effect of plastic strain on the subsequent tensile ductility of steel hydrogenated before straining.

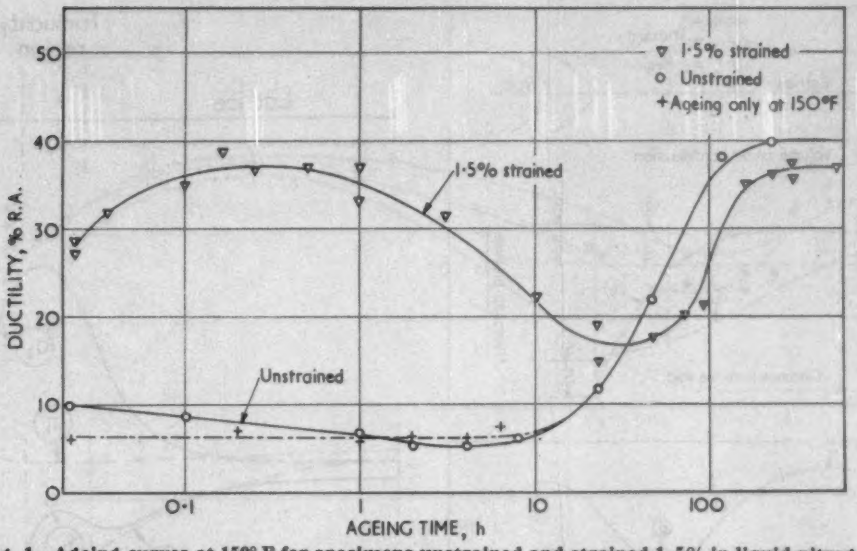


Fig. 1—Ageing curves at 150° F for specimens unstrained and strained 1·5% in liquid nitrogen

MATERIALS AND PROCEDURE

Specimen Preparation

Material was taken from a commercial heat of electric-furnace aircraft-quality SAE–AISI 4340 steel furnished by Republic Steel Corporation in the form of hot-rolled ⅝-in. bars. The chemical composition is listed in Table I.

Tensile specimens at a strength level of 230,000 lb/in² were prepared according to the sequence described previously.[7]

The tensile specimen had a 0·212-in. dia. with a 2-in. radius on the specimen barrel to ensure fracture at the specimen mid-point.

Hydrogen Charging

The tensile specimens were de-greased in carbon tetrachloride and then cathodically charged for 5 min in a 4% sulphuric acid solution at a current density of 0·02 A/in². Immediately after electrolytic charging, the specimens were cadmium-plated in a sodium cyanide bath for 15 min with a current density of 20 A/ft².

The hydrogen distribution in specimens charged under these conditions is highly non-uniform.[7] The surface layers contain a high hydrogen concentration, while the core is still hydrogen free.

The hydrogen concentration may be homogenized by a baking treatment at 300° F.[8] The baking treatment drives the surface hydrogen into the specimen core, since the cadmium plate acts as a barrier to hydrogen outgassing. In the present investigation a standard baking treatment of 1 h at 300° F was used.

Hydrogen Analyses

Hydrogen analyses were of no value, since they were incapable of indicating any increase in the total hydrogen content before and after charging. This was true for several other heats which were of almost identical analyses but different as-received hydrogen contents, and which displayed the same behaviour after hydrogenation. The inference is strong (and is supported by other work to be published shortly) that, in these high-strength steels, only small amounts of hydrogen will produce embrittlement. It further follows that the hydrogen obtained by charging is most likely in a different form (solution) than that which has come through from steelmaking practice.

That the charging techniques employed here introduced a reproducible amount of hydrogen each time is evident from the consistency of the data. In addition, the reduction in area after simple ageing is a sensitive measure of the overall hydrogen content and this was definitely reproducible.

Straining, Ageing, and Testing

Straining at room temperature was not satisfactory, because of crack formation early in the strain history of the specimen. For example, specimens strained to 1·5% R.A. (reduction in area) contained a multitude of tiny cracks, although the specimen fractured with a ductility of 10% R.A. Thus, the strain range was severely limited at room temperature.

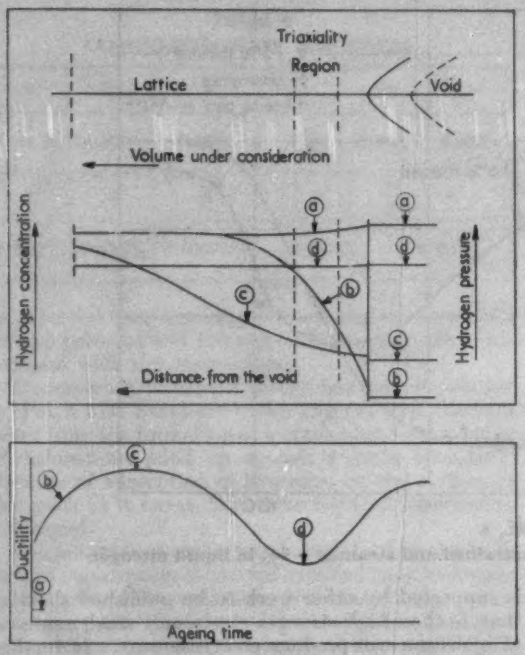
The disappearance of hydrogen embrittlement at low temperatures suggested that early crack formation could be eliminated by straining hydrogenated specimens at — 321° F. This supposition proved correct; it was possible to strain hydrogenated specimens to greater than 12% R.A. at — 321° F without forming cracks.

The straining process was performed with the specimen immersed in liquid nitrogen and the strain was continuously recorded by an electrical radial strain gauge coupled to a recorder.

The ductilities resulting from the various charging and testing conditions are summarized in Table II.

The disappearance of hydrogen embrittlement at — 321° F is evident.

Subsequent to straining, the specimens were aged at one of several temperatures, depending upon the phase of the investigation. Final testing was done in a hydraulic testing machine at a constant crosshead speed of 0·05 in./min.



The scales have been adjusted so that at equilibrium, concentration and pressure have equivalent values

Fig. 2—Schematic representation of hydrogen diffusion to the voids during ageing after straining in liquid nitrogen

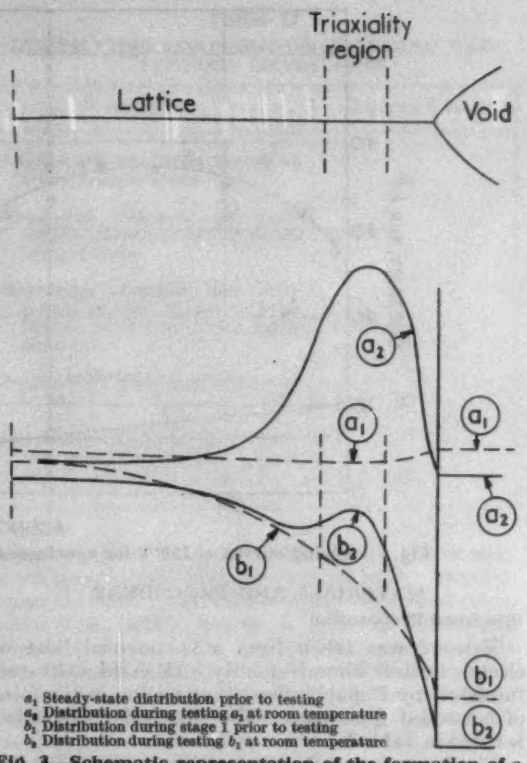

Triaxiality region
Lattice
Void
a_1 Steady-state distribution prior to testing
a_2 Distribution during testing a_1 at room temperature
b_1 Distribution during stage 1 prior to testing
b_2 Distribution during testing b_1 at room temperature

Fig. 3—Schematic representation of the formation of a hydrogen gradient during testing at room temperatures for two initial distributions

RESULTS AND DISCUSSION

Straining at — 321° F after Hydrogenation

1·5% Strain—In the initial investigation hydrogenated specimens were strained 1·5% at — 321° F and aged at 150° F. The resulting ageing curves are presented in Fig. 1.

It is evident that strain causes a remarkable change in the ageing characteristics of hydrogenated steel. In the ageing curve for strained specimens, three distinct stages may be distinguished. During stage 1 the ductility increases from 22% R.A. to 37% R.A. In the second stage the ductility decreases from 37% R.A. to a minimum value of about 17% R.A. In stage 3 the ductility again increases in a manner similar to the unstrained ageing curve.

The variation in ductility during stages 1 and 2 is particularly striking when compared with the unstrained ageing curve. In the same time interval, the ductility of unstrained specimens decreases slightly and then begins to increase, presumably owing to hydrogen outgassing.* These data offer an opportunity to evaluate critically proposed theories of hydrogen embrittlement. In particular, a valid theory must yield a logical explanation for the ductility variations during stages 1 and 2.

Prior to straining, a steady-state distribution exists between hydrogen in the lattice and hydrogen in the voids. As many atoms of hydrogen leave the lattice for the voids as go from the voids to the lattice. This distribution is the result of the interaction between hydrogen pressure in the voids and hydrogen concentration in the lattice.

Straining changes the steady-state distribution by increasing the occlusive capacity of the voids. Establishment of a new steady-state distribution requires hydrogen to move from the lattice to the voids. During straining at — 321° F, hydrogen is immobile; however, at 150° F the hydrogen diffusion rate is vastly increased and hydrogen will diffuse to the voids during the ageing treatment.

Presuming, for the moment, that the pressure theory of hydrogen embrittlement is correct, then variations in specimen ductility should represent changes in void pressure. Immediately after straining, the void pressure is a minimum because of the increased void capacity. During stage 1, the void pressure will certainly increase as hydrogen diffuses to the voids. The pressure theory predicts, therefore, that the ductility should initially decrease upon ageing. Presumably, the ductility would decrease until the new steady-rate distribution was established, at which time the void pressure would be a maximum. After this, the ductility may increase because of hydrogen pressure loss through outgassing.

The experimental results contradict the predictions of the pressure theory. Instead of the required

*The minimum in the standard ageing curve results from the multi-temperature treatment involved in specimen preparation and ageing. This is suggested by the absence of a minimum in the curve for specimens aged directly at 150° F. It is thought that this behaviour may be related to the variation of hydrogen solubility with temperature.

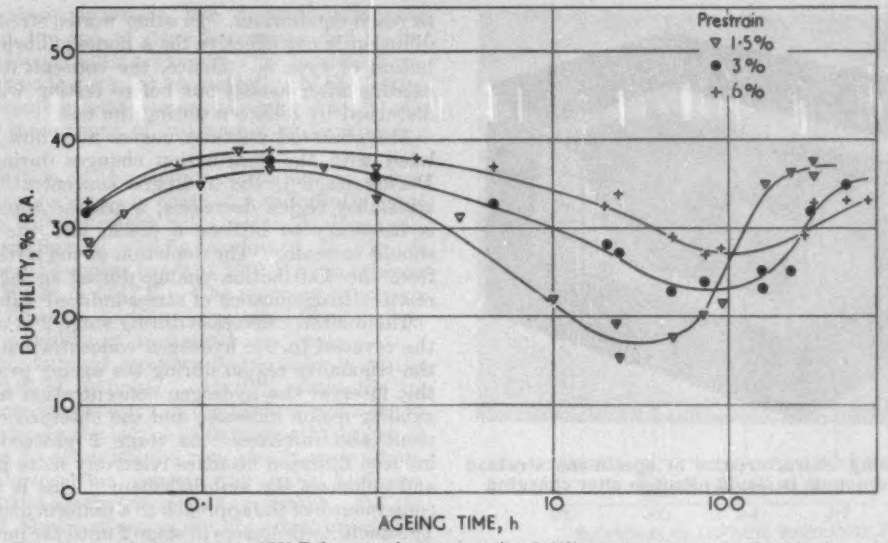


Fig. 4—Ageing curves at 150° F for specimens strained different amounts in liquid nitrogen

ductility decrease during stage 1, the observed ductility actually increases. Furthermore, the pressure theory allows only one reversal in the ductility curve, whereas the observed curve shows two reversals.

The surface adsorption mechanism of embrittlement is also incompatible with the experimental results. In this mechanism embrittlement results from a lowering of the surface energy caused by hydrogen adsorption on a crack surface. Presumably, the embrittlement severity is dependent upon the concentration of the adsorbed hydrogen. From classical adsorption theory,[9] the surface concentration of an adsorbed gas is a monotonic function of the pressure of the gas phase in contact with the surface. The adsorption theory thus requires increasing embrittlement during initial ageing, since the void pressure increases in this range. This requirement is at variance with the experimental results; hence the surface adsorption mechanism is unsatisfactory.

The inadequacy of the current theories compels consideration of a different mechanism. Previous reports from this laboratory[7, 10] have suggested that the severity of hydrogen embrittlement is determined by the dual action of hydrogen and stress. The increase in embrittlement with increasing hydrogen concentration has been amply demonstrated.[10] For a given hydrogen content the embrittlement becomes greater as the stress concentration increases. This effect has been shown by experiments on notched specimens.[10] Thus, as the hydrogen content decreases, a greater stress is necessary to attain a given degree of embrittlement.

On a microscale the voids may be considered equivalent to a multitude of tiny internal notches. The voids are then potential stress-raisers. When a stress is applied to the material a multi-axial stress state is created in the lattice region around each void. The extent of the multi-axial stress-state region cannot be determined quantitatively. At some point within this region, however, the stress state will be most severe. This is the point of maximum triaxiality. Plasticity theory and experimental work by Green[11] and Brown[12] demonstrate that the point of maximum triaxiality is beneath the notch surface; the location depends essentially upon the notch acuity.

These ideas, applied on a microscale, suggest an unique concept of hydrogen embrittlement. It is postulated that the degree of embrittlement varies directly as the hydrogen concentration in the region of maximum triaxiality. On this basis the observed ageing curve reflects the variations in hydrogen concentration in the maximum-triaxiality region.

This concept is supported by an analysis of the changes in hydrogen distribution after straining. The distribution at fracture is determined by two processes: (*a*) hydrogen diffusion during ageing and (*b*) hydrogen diffusion during the test. The distribution changes during ageing are discussed first, and then the influence of diffusion during the tensile test is considered.

A schematic representation of the effect of ageing is presented in Fig. 2 which depicts the hydrogen distribution in the lattice and the voids at various states of the ageing process. The steady-state hydrogen distribution prior to straining is assumed to have the shape indicated by curve *a*.

When ageing commences, subsequent to straining, the hydrogen moves from the lattice to the voids. This diffusion process rapidly depletes the void boundary area of hydrogen; however, the hydrogen concentration in the triaxiality region is only slightly diminished. The distribution in this state corresponds to curve *b*.

The diffusion process will proceed until a new steady-state distribution is established, corresponding to curve *d*. The lattice hydrogen concentration in the new steady state is lower than the concentration prior to straining because of the increased void capacity.

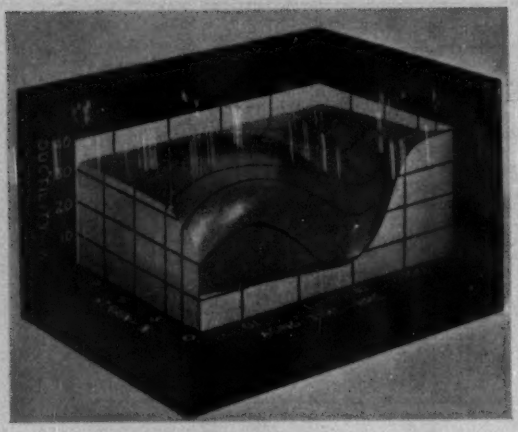


Fig. 5—Ageing characteristics of specimens strained different amounts in liquid nitrogen after charging

At an intermediate stage in the ageing process the distribution curve must be of type *c*. This is evident from consideration of conventional diffusion laws and the shape of curves *b* and *d*.

The hydrogen concentration trend in the triaxiality region thus undergoes a reversal during the ageing process. The concentration is initially high; it slowly decreases during stage 1 and subsequently increases during stage 2. It may also be noted that the void pressure increases continually throughout the ageing treatment.

Diffusion during ageing has been discussed; it is now necessary to consider diffusion during the tensile test. Concurrent research[10] has suggested that hydrogen will concentrate in a highly stressed region and thereby create a concentration gradient in conformity with the stress gradient. This concentration of hydrogen is considered to be induced by the severe stress state, and is not a classical diffusion process.

The magnitude of this stress-induced gradient is dependent upon the basic distribution before testing, as illustrated in Fig. 3. With an equilibrium distribution of hydrogen (distribution a_1), a high concentration with a steep gradient may be formed in the triaxiality region during the test (distribution a_2). However, when the lattice has been depleted (distribution b_1), as during stage 1, and the equilibrium capacity of the void is not attained, a significant stress-induced gradient will not be formed, since the hydrogen will be drawn into the void in an attempt to reach equilibrium. In other words, stress-induced diffusion is not effective for a non-equilibrium distribution of type b_1. Hence, the concentration trend existing after ageing but before testing will not be disturbed by diffusion during the test.

The observed ductility curves may now be correlated with the distribution changes during ageing. During stage 1, the hydrogen concentration in the triaxiality region decreases; a greater applied stress is necessary to initiate a crack, and the ductility should increase. The depletion of the lattice results from the distribution change during ageing and the relative insignificance of stress-induced diffusion.

The ductility decrease during stage 2 is caused by the reversal in the hydrogen concentration trend in the triaxiality region during the ageing process. In this interval the hydrogen concentration in the triaxiality region increases and the observed embrittlement also increases. As stage 2 proceeds, stress-induced diffusion becomes relatively more important and enhances the embrittlement. This is a natural consequence of the approach to a uniform distribution. The ductility decreases in stage 2 until the new steady-state distribution is established, or until the outgassing effect becomes important. The ductility increase in stage 3 is attributed to gross outgassing of hydrogen from the specimen.

The hypothesis that hydrogen embrittles the maximum-triaxiality region yields a consistent interpretation of the observed ageing curve. In particular, the ductility trends in stages 1 and 2 may be explained. The hydrogen precipitated in the voids is non-damaging and of importance only in determining the steady-state hydrogen distribution.

Influence of strain—From the hypothesis, it is evident that the strain magnitude should exert an influence on the ageing characteristics. The degree of steady-state embrittlement depends primarily on the ratio of lattice hydrogen concentration to void hydrogen concentration, since the total hydrogen content of the specimen remains constant. As the strain is increased, the steady-state hydrogen content of the voids is increased, and the lattice hydrogen concentration must decrease.

The pseudo-recovery observed in stage 1 is accelerated by increasing strain, in agreement with the postulated mechanism. This behaviour is shown by the ageing curves (Fig. 4) for specimens strained 3% or 6% at − 321° F and aged at 150° F. The influence of strain on the ageing characteristics is summarized in Fig. 5. The greater strain increases the driving force for hydrogen diffusion from the lattice to the voids.

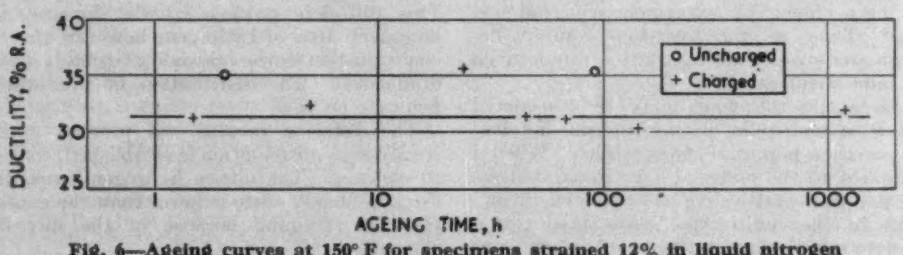


Fig. 6—Ageing curves at 150° F for specimens strained 12% in liquid nitrogen

As the strain increases, the ductility minimum observed at the end of stage 2 increases and is displaced to longer ageing times. This behaviour results from two factors: (*a*) the depletion of the lattice hydrogen content with increasing strain and (*b*) the increasing importance of outgassing at long ageing times.

Extrapolation of the shapes of the ageing curves to larger strains suggests that, at a sufficiently large strain, the embrittlement will essentially disappear. This expectation is vividly confirmed in Fig. 6, which shows the ageing curve at 150° F for specimens strained 12% at — 321° F. The recovery curve is a horizontal line at a ductility level equal to or slightly below the ductility of uncharged specimens.

The strain-induced recovery is due entirely to the redistribution of hydrogen. At 12% strain the increased occlusive capacity of the voids is sufficient to drain completely the lattice of damaging hydrogen in an attempt to establish the new steady-state distribution. During this process the gross hydrogen content of the specimens remains constant. On the other hand, elastic straining did not affect the ageing properties, i.e. unstrained and elastically-strained specimens exhibited identical ageing curves. This is striking evidence of the localized redistribution of hydrogen resulting from plastic deformation.

Influence of ageing temperature—The diffusion-controlled nature of the mechanism is demonstrable by ageing at different temperatures. After straining 1·5% at — 321° F, specimens were aged at different temperatures. Stage 1 has been studied at 150° F, 80° F, 32° F, and — 15° F. The results are summarized in Fig. 7.

The diffusion-controlled behaviour is evidenced by the displacement of the ageing curve to longer times at low ageing temperatures. The phenomenon is further indicated by an Arrhenius plot of the data (Fig. 8). The ductility at the mid-point (corresponding to R.A. of 30%) of stage 1 is plotted against the reciprocal of the ageing temperature. The activation energy obtained from this plot is 8500 cal/g, which agrees well with published values[13] of the activation energy for diffusion of hydrogen through iron.

The embrittlement process in stage 2 is also diffusion-controlled. Ageing curves at 300° F, 150° F, and 80° F are presented in Fig. 9 and the corresponding Arrhenius plot in Fig. 10. An activation energy of 9600 cal/g is observed, which is well within the expected experimental error. These results provide

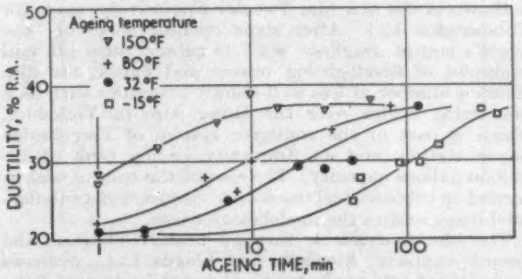


Fig. 7—Stage 1 at four ageing temperatures for specimens strained 1·5% in liquid nitrogen

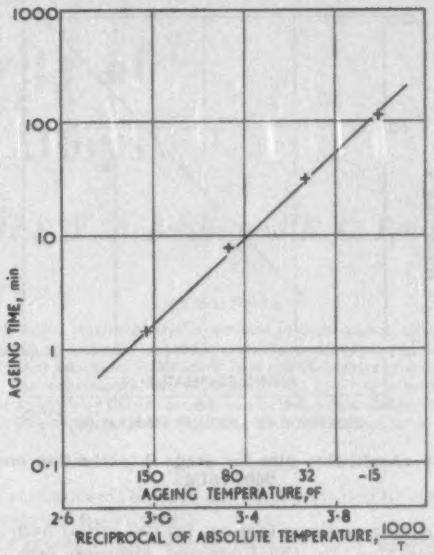


Fig. 8—Arrhenius plot for stage 1 (activation energy 8500 cal/g)

strong corroboration for the proposed embrittlement mechanism, since the diffusion-controlled nature of the hypothesis has been confirmed.

GENERAL DISCUSSION

The hydrogen embrittlement concept proposed here must be compatible with the known influence of temperature and strain rate. The explanation of these behaviours lies in a further analysis of hydrogen diffusion during the test. The severe triaxial stress state created around the voids is presumably responsible for this aspect of the diffusion process. Hydrogen diffuses to the highly stressed region and concentrates there; a steep hydrogen-concentration gradient may be created by a severe stress state.

Mechanical tests are usually performed at relatively slow strain rates; thus, ample opportunity exists for creation of a severe concentration gradient in the triaxially stressed volume. As the stress continually increases, the critical combination of hydrogen concentration and stress state may be attained, and a crack opens in the lattice at the point of maximum triaxiality.

The magnitude of the concentration gradient created in the triaxially stressed region depends

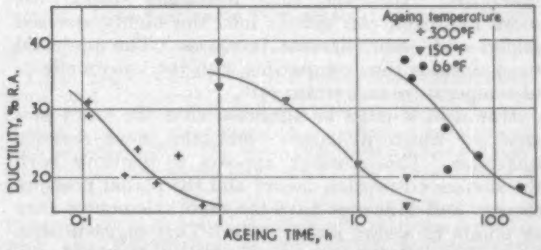


Fig. 9—Stage 2 at three ageing temperatures for specimens strained 1·5% in liquid nitrogen

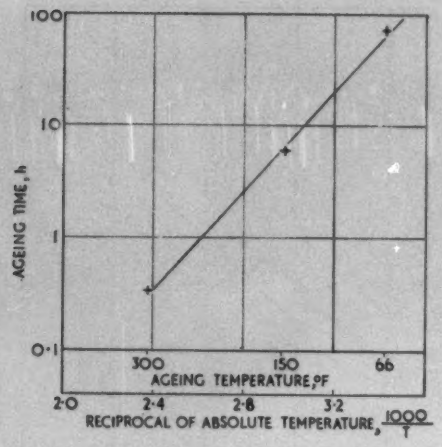


Fig. 10—Arrhenius plot for stage 2 (activation energy 9600 cal/g)

primarily upon three factors: (*a*) the initial hydrogen concentration, (*b*) the hydrogen diffusion rate, and (*c*) the time during which hydrogen may diffuse.

The disappearance of hydrogen embrittlement at low temperatures results from the decrease in the hydrogen diffusion rate with decreasing temperature. Although the stress-induced driving force is presumably independent of the temperature, the mobility of the atoms at the low temperatures is strongly retarded; thus the embrittlement decreases.

The disappearance of hydrogen embrittlement at high temperatures can be explained on the basis of the competing effects of the stress-induced driving force which tends to promote concentration of the hydrogen in the triaxiality region and the classical concentration-equalizing force which promotes homogenization. At high temperatures, the homogenizing force which increases with temperature is sufficient to overpower the stress-produced gradient which is temperature-independent, with the result that the embrittlement decreases. It should also be noted that the notch sensitivity of the steel decreases with increasing temperature; thus, the voids should be less effective in creating a region of severe stress state.

The strain-rate dependence of hydrogen embrittlement reflects variations in the time available for hydrogen to diffuse into the highly stressed regions. In a fast strain-rate test there is insufficient time for a damaging quantity of hydrogen to diffuse into the region of maximum triaxiality and embrittlement is minimized. However, with decreasing strain rate, more hydrogen can diffuse into the highly stressed region and embrittlement increases. The proposed mechanism is thus compatible with the known effects of temperature and strain rate.

However, it must be admitted that the exact process by which hydrogen embrittles steel remains unknown. This research appears to disprove both the surface adsorption theory and the planar pressure theory, and indicates that the embrittlement occurs at points of severe stress state. This suggests that hydrogen embrittlement is but one facet of the general problem of fracture, and that a satisfactory theory of hydrogen embrittlement may have to await development of a general theory of fracture.

Acknowledgments

The authors wish to express their appreciation to the Aeronautical Research Laboratory, Wright Air Development Center, for sponsorship of this investigation under contract No. AF 33(616)–3431, and for permission to publish these data. The co-operation of the Republic Steel Corporation, which provided the steel employed in this study, is gratefully acknowledged.

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International Mineral Processing Congress

The Institution of Mining and Metallurgy is proposing to hold an International Congress of Mineral Processing in London from 6th to 9th April, 1960. Enquiries should be addressed to the Secretary of the Institution, 44 Portland Place, London, W.1.

Film on Tubular Engineering

A wide variety of tubular-steel structure in the U.K. is shown in the new film *Tubular Engineering*, made for Tubewrights Ltd. After some opening shots of 'the world's largest dragline' with its tubular-steel jib, and examples of floodlighting towers and masts, the film shows a number of less well-known structures such as a bow-string bridge over the River Aire in Yorkshire, which is part of the conveyor system of Ferrybridge power station, and an Admiralty testing tank of 12-million gallons capacity. The roof of the testing tank is carried on tubular-steel trusses and booms, and a tubular-steel boom carries the models under test.

The film is available through branch offices of the parent company, Stewarts and Lloyds Ltd.; overseas borrowers should apply to the export department of the head office in Glasgow.

The Electrical Resistivity of High-purity Iron–Carbon Alloys

By S. V. Radcliffe and E. C. Rollason

SYNOPSIS

The electrical resistivities of a number of iron–carbon alloys containing up to 4·3 wt-% carbon have been measured, and a simple relationship has been established between resistivity and composition. The relationship can be used as the basis of a method of carbon analysis by direct measurement of electrical resistivity. The resistivity of iron carbide (Fe_3C) has been determined as 79·5 $\mu\Omega$-cm. 1500

Introduction

SEVERAL ATTEMPTS have been made previously to establish a definite relationship between electrical resistivity and carbon content for commercial plain carbon and alloy steels.[1–3] However, no simple relationship has been discovered and, as one consequence, electrical methods of carbon analysis have not found acceptance.

Some results of recent measurements at room temperature of the specific resistivities of a number of annealed, plain carbon steels[4] are presented in Fig. 1. There is a fairly steady rise in resistivity with increasing carbon content up to about 0·25%. Above this value, the scatter between the resistivities of steels of similar carbon content is considerable. The most probable cause of scatter is the variation from steel to steel of the amounts of elements other than carbon. Many of these 'impurity elements' are present in solid solution and therefore would be expected to contribute to the resistivity in proportion to their concentration. Thus, it appeared likely that in iron–carbon alloys free from such impurities a simple relationship might be found between resistivity and carbon content. Such a relationship would be of value both as the basis of a method of carbon analysis and as a guide to the interpretation of the kinetics of phase transformations in the alloys studied by changes in electrical resistivity.

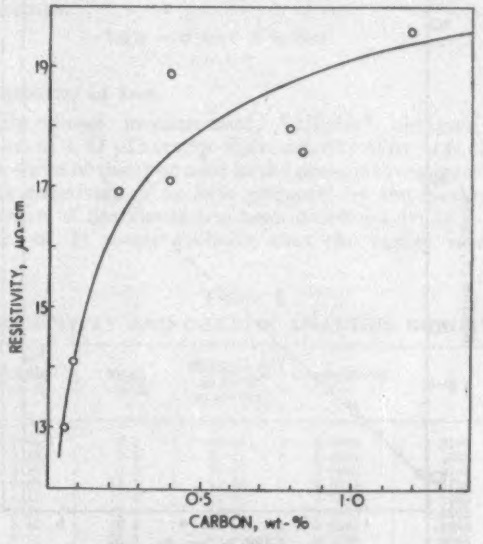

Fig. 1—Effect of carbon content on the electrical resistivity of plain carbon steels

The present study was undertaken with the object of ascertaining the exact nature of the relationship between resistivity and composition for high-purity iron–carbon alloys up to the composition of cementite (Fe_3C).

EXPERIMENTAL PROCEDURE

A series of alloys containing up to 1·3 wt-% carbon was prepared by gas-carburizing specimens of pure iron in the form of wires 0·010 in. dia. and 8 in. long. The wires were made from vacuum-melted deoxidized iron (99·96% Fe) supplied by the British Iron and Steel Research Association. Carburizing was carried out at a constant temperature of 925° C in an atmosphere of nitrogen saturated with benzene vapour. The required range of carbon contents was obtained by varying the time of carburizing.

Two alloys in the eutectic range of composition were prepared from the B.I.S.R.A. iron and high-purity graphite by induction melting and chill casting. The hypoeutectic alloy was remelted under argon and a small tubular specimen suitable for resistivity measurements was formed by suction casting into a smooth-bore quartz tube of 3·5 mm i.d. Following the determination of the resistivity, the regularity of the tube dimensions was confirmed from measurements made by a travelling microscope on sections cut at intervals along the length. In the case of the eutectic alloy, a specimen was sliced from the chill-cast ingot and ground to a 2·5 mm square cross-section. Both specimens were cut to a length of 60 mm.

Paper MG/NA/160/56 of the Isothermal Transformations and Hardenability Group (Thermal Treatment Committee) of the Metallurgy (General) Division of the British Iron and Steel Research Association, received on 29th October, 1957. The views expressed are the authors' and are not necessarily endorsed by the Committee as a body.

Dr. Rollason is Professor of Industrial Metallurgy at Birmingham University; Dr. Radcliffe, who was formerly with the Department of Metallurgy, University of Liverpool, is now at the Massachusetts Institute of Technology.

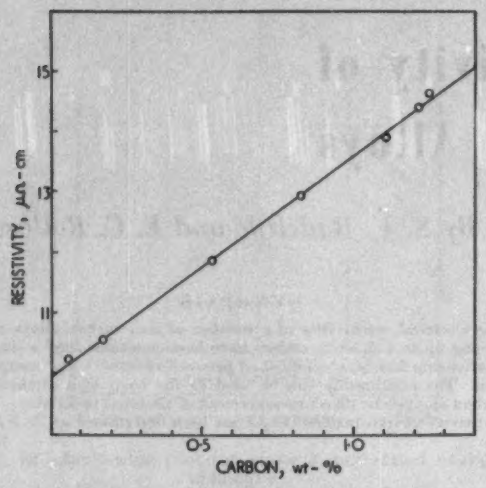

Fig. 2—Effect of carbon content on the resistivity of iron–carbon alloys

Attempts to prepare a specimen of pure cementite in a form suitable for resistivity measurements were unsuccessful.

The electrical resistivities of the specimens were measured at room temperature by the potential-drop method, using a pure platinum wire of known resistance as a reference standard.

The homogeneity of each specimen was confirmed by micro-examination of cross-sections taken from the ends and the central portions of the length. The examination confirmed also that the heat-treatment given to the alloys had resulted in the formation of a series of microstructures containing a similar fine pearlite together with varying proportions of free ferrite or cementite.

Finally, the series was analysed for carbon content by a standard chemical method.

EXPERIMENTAL RESULTS

The measured resistivities of the pure iron–carbon alloys containing up to 1·3% carbon are shown in Fig. 2. The linearity of the relationship between resistivity and composition is in marked contrast with the considerable scatter exhibited by the results for the plain carbon steels shown in Fig. 1.

However, a simple linear relationship does not hold for pure alloys which contain much more than 1·3% carbon, as can be seen from Fig. 3. Here the results are shown for the complete series of alloys, and it is apparent that the points which represent the two alloys of highest carbon content do not fall on the extrapolation of the straight-line relationship of Fig. 2. The discrepancy is well outside the possible experimental error.

The full results of the resistivity measurements and of the carbon analysis for the series are given in Table I.

DISCUSSION

General Discussion

For a number of metallic systems, the specific conductivity of aggregates of two constituents has been found to be very nearly proportional to their volume composition.[5] However, as would be expected from the linearity of the direct plot of resistivity versus composition and the small difference between the specific volumes of alpha-iron and cementite, the results obtained for the iron–carbon alloys do not lie on a straight line when plotted in this form.

It has been observed that some physical properties (e.g. density, conductivity, permittivity, permeability) of mixtures of different constituents can be calculated from a knowledge of the appropriate property for the pure constituents. If the ith constituent is assumed to occupy θ_i of the total volume ($\Sigma_i \theta_i = 1$) and the value of the particular property for the pure constituent is ϵ_i, the resultant property value for the mixture can be calculated from an empirical equation of the type:

$$\epsilon^k = \Sigma_i \theta_i . \epsilon_i^k \qquad \text{.....(1)}$$

where $-1 < k < +1$.

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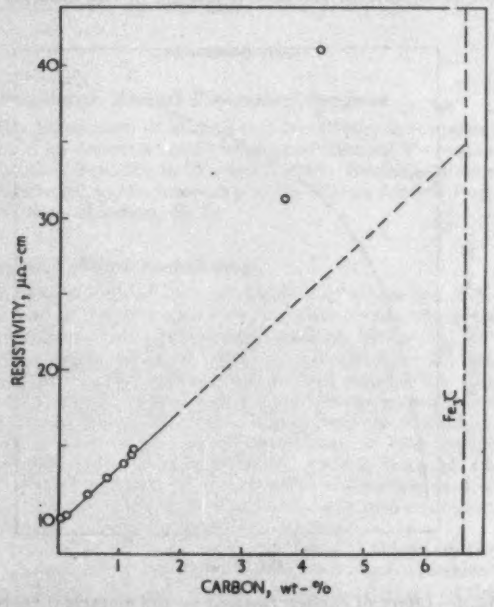

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Substituting for ϵ^k in equation (1):

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and since $\Sigma_i \theta_i = 1$, then:

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A plot of the logarithm of the resistivity against volume composition will give a straight line for mixtures to which equation (2) is applicable. Such a linear relationship has been established experimentally for a number of mixtures.[8]

The experimental results obtained for the pure iron–carbon alloys are shown in Fig. 4 plotted in conformity with equation (2). It is apparent from the straight line drawn through the experimental points that the resistivity/composition relationship for pure iron–carbon alloys is also of this type.

From Fig. 4, extrapolated values for the resistivity of pure iron and of cementite are 9·92 and 79·5 μΩ-cm, respectively. When these values are used in direct plots of resistivity against volume of cementite, a smooth continuous curve can be drawn over the whole of the composition.

Thus, in the case of the resistivity of iron–carbon alloys, equation (2) can be rewritten as:

$$\ln \rho = (1 - \theta) \,.\, \ln \rho_{Fe} + \theta \,.\, \ln \rho_{Fe_3C} \qquad \ldots\ldots (3)$$

where ρ is the resistivity of the alloy and θ is the volume fraction of cementite. On substituting the values obtained above for ρ_{Fe} and ρ_{Fe_3C}, this equation becomes:

$$\log \rho = 0{\cdot}90\,\theta + 0{\cdot}996 \qquad \ldots\ldots\ldots (4)$$

Resistivity of Iron

By direct measurement, Pallister[9] obtained a value of 9·81 μΩ-cm for the resistivity of an annealed pure iron of the type used in the present investigation. The resistivity of an iron prepared by the National Bureau of Standards has been determined[10] as 9·71 μΩ-cm. It seems probable that the higher values obtained for the B.I.S.R.A. iron can be attributed to slight supersaturation of ferrite with carbon.

The isothermal precipitation of carbon retained in solid solution in iron by quenching is known to be slow at low temperatures. Consequently, after an annealing treatment, either extremely slow cooling or prolonged holding at intermediate temperatures is necessary to ensure complete precipitation of carbon. In the present case, and in that of Pallister, it is possible that these conditions have not been met. Dijkstra[11] and Köster[12] have shown that the precipitation of 0·01% carbon from solution causes a decrease in electrical resistivity of 2·5%. The value quoted for the resistivity of the N.B.S. iron is 2·12% lower than that obtained in the present investigation. Thus, if the experimental errors likely in the resistivity measurements are taken into account, the slightly higher resistivities obtained for the B.I.S.R.A. iron can be attributed to the retention of up to 0·005% carbon in solid solution in alpha-iron.

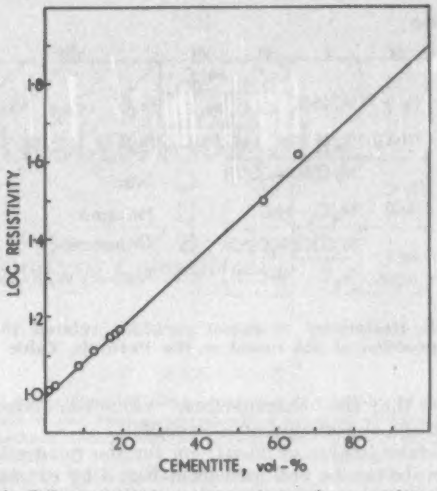

Fig. 4—Effect of volume-percentage of cementite on the resistivity of iron–carbon alloys

The Resistivity of Iron Carbide (Fe_3C)

The following values have been reported for the resistivity of the cementite present in plain carbon steels:

45·0 μΩ-cm	Le Chatelier[1]
70·0 „	Stäblein[2]
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Each of these values was obtained by extrapolation from data for steels containing less than 1·5% carbon. No direct measurement of the resistivity of pure cementite has been made. Benedicks attempted to allow for the effects of the manganese and silicon present in commercial steels and thus calculated 24·7 μΩ-cm as the 'characteristic' resistivity of cementite. However, the calculation assumed that a constituent "ferronite," which is a solid solution of 0·27% carbon in iron, exists in steels containing more than 0·5% carbon, and that the resistivity of pure iron is 7·6 μΩ-cm. In view of present knowledge, neither of these assumptions is justifiable and it

Table I

RESISTIVITY AND CARBON ANALYSIS RESULTS

Carbon, wt-%	Fe_3C, vol-%	Resistivity at 24° C ρ, μΩ-cm	Conductivity $(1/\rho)$	Log ρ
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0·17	2·6	10·57	0·0946	1·0240
0·53	8·2	11·87	0·0843	1·0741
0·83	12·7	12·94	0·0773	1·1120
1·12	17·2	13·90	0·0720	1·1430
1·23	18·8	14·43	0·0693	1·1593
1·26	19·3	14·63	0·0684	1·1653
3·74	56·7	31·36	0·0319	1·4963
4·33	65·7	41·17	0·0243	1·6145

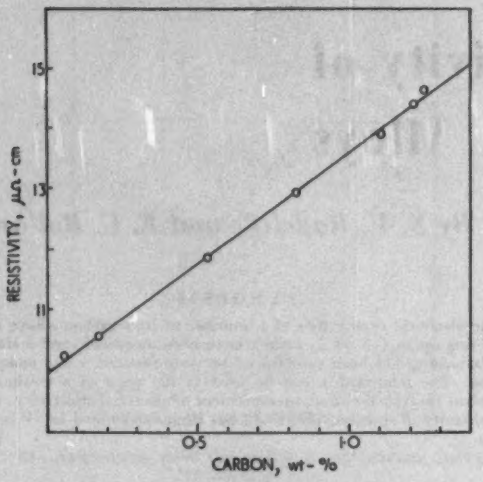

Fig. 2—Effect of carbon content on the resistivity of iron–carbon alloys

Attempts to prepare a specimen of pure cementite in a form suitable for resistivity measurements were unsuccessful.

The electrical resistivities of the specimens were measured at room temperature by the potential-drop method, using a pure platinum wire of known resistance as a reference standard.

The homogeneity of each specimen was confirmed by micro-examination of cross-sections taken from the ends and the central portions of the length. The examination confirmed also that the heat-treatment given to the alloys had resulted in the formation of a series of microstructures containing a similar fine pearlite together with varying proportions of free ferrite or cementite.

Finally, the series was analysed for carbon content by a standard chemical method.

EXPERIMENTAL RESULTS

The measured resistivities of the pure iron–carbon alloys containing up to 1·3% carbon are shown in Fig. 2. The linearity of the relationship between resistivity and composition is in marked contrast with the considerable scatter exhibited by the results for the plain carbon steels shown in Fig. 1.

However, a simple linear relationship does not hold for pure alloys which contain much more than 1·3% carbon, as can be seen from Fig. 3. Here the results are shown for the complete series of alloys, and it is apparent that the points which represent the two alloys of highest carbon content do not fall on the extrapolation of the straight-line relationship of Fig. 2. The discrepancy is well outside the possible experimental error.

The full results of the resistivity measurements and of the carbon analysis for the series are given in Table I.

DISCUSSION

General Discussion

For a number of metallic systems, the specific conductivity of aggregates of two constituents has been found to be very nearly proportional to their volume composition.[5] However, as would be expected from the linearity of the direct plot of resistivity versus composition and the small difference between the specific volumes of alpha-iron and cementite, the results obtained for the iron–carbon alloys do not lie on a straight line when plotted in this form.

It has been observed that some physical properties (e.g. density, conductivity, permittivity, permeability) of mixtures of different constituents can be calculated from a knowledge of the appropriate property for the pure constituents. If the ith constituent is assumed to occupy θ_i of the total volume ($\Sigma_i \theta_i = 1$) and the value of the particular property for the pure constituent is ϵ_i, the resultant property value for the mixture can be calculated from an empirical equation of the type:

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where $-1 < k < +1$.

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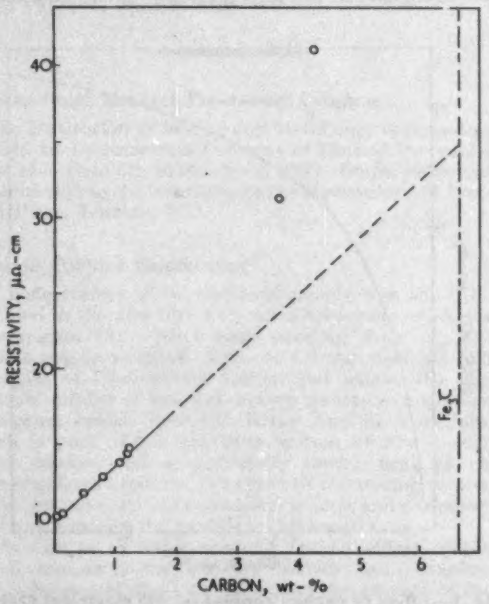

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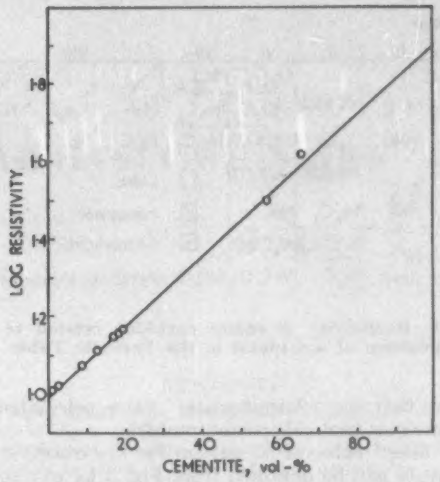

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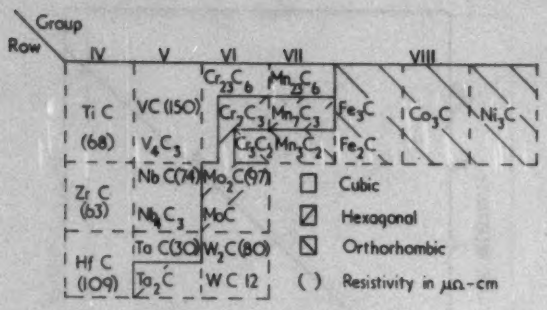

Fig. 5—Resistivity of metal carbides related to the position of the metal in the Periodic Table

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The published resistivities of the known metal carbides[13] are shown in Fig. 5 on a diagram after Goldschmidt, which relates carbide structure to the position of the metal in the Periodic Table. Unfortunately the resistivities of the carbides adjacent to those of iron in this diagram are unknown and it is difficult to detect in the quoted values any definite trend with change in position in the diagram. However, with the exception of tantalum carbide (TaC), all the known resistivities are greater than 63 μΩ-cm and most are in the range 63–109 μΩ-cm. This fact, together with the high purity of the ferrite–cementite mixtures examined in the present investigation, suggests the acceptance of the value obtained for the resistivity of cementite of 79·5 μΩ-cm, in preference to the values published previously.

Confidence in the figure is also prompted by the fact that the extrapolation of the same line in Fig. 4 yields a resistivity value for pure iron which is in good agreement with the experimentally determined values of Pallister and others.

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The linear relationship established between electrical resistivity and volume composition indicates that measurements of resistivity can be used as a method of carbon analysis for pure iron–carbon alloys in the annealed condition. Resistivity measurements on gas-carburized wires proved successful as a means of non-destructive analysis to enable the specimens to be sorted into groups of similar composition. The effect of the presence of bainite structures on the relationship is unknown but, in view of the conformity of the range of ferrite–carbide structures examined, it is probable that structures containing upper bainite would conform to equation (4).

CONCLUSIONS

The results obtained and the conclusions drawn from them can be summarized as follows:

(1) The relationship between the electrical resistivity and composition of annealed, high-purity iron–carbon alloys can be expressed by the equation:

$$\log \rho = 0{\cdot}90\,\theta + 0{\cdot}996.$$

(2) By means of this relationship, measurements of electrical resistivity can be used to determine the carbon content of pure iron–carbon alloys.

(3) The electrical resistivity of iron carbide (Fe_3C) is 79·5 μΩ-cm.

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The Spectrographic Analysis of Slags

By the B.I.S.R.A. Methods of Analysis Committee

SYNOPSIS

The report describes the investigation of a number of accepted methods of slag analysis, carried out to ascertain whether any of the methods could be modified to give results within 30 min and be reproducible to within ± 3%. Pelletting, tipping, dry powder, and solution techniques are examined, and among the variables studied attention is given to the making of the powdered samples, homogeneity of the fused melt, effect of the fusion mixture ratio, polarity of sample, and (in the case of solution techniques) the effect of electrode shape and preliminary treatment. None of the solid sample or powder techniques was satisfactory but a solution method was formulated which gave results most nearly conforming to the criteria adopted. Details of the recommended solution technique, together with examples of results obtained, are presented.

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Introduction

A STUDY GROUP WAS FORMED from the Spectrographic Analysis Sub-committee of the British Iron and Steel Research Association to investigate the analysis of steelmaking slags. Its purpose was to endeavour to formulate a method which would give the complete analysis of a slag with an accuracy of ± 3% in 30 min.

The constitution of the study group, which held its first meeting in May 1952, was: Mr. A. Argyle (Convenor from Jan. 1954), British Cast Iron Research Association; Mr. G. L. Mason (Convenor until Jan. 1954), formerly with United Steel Companies Ltd.; Mr. W. L. Dutton, Imperial Chemical Industries Ltd.; Mr. L. Gwilliam, United Steel Companies Ltd.; Mr. M. Z. de Lippa, Consett Iron Company Ltd.; Mr. S. Muir, Stewarts and Lloyds Ltd.; Mr. W. S. Sykes, Steel, Peech and Tozer; Mr. R. H. Tyas (Secretary), British Iron and Steel Research Association.

It was agreed that to develop a reliable method for the analysis of slags, refractories, ores, etc., the study group would examine other spectrographic methods available for the analysis of non-metallic materials when these were appropriate. Such methods can be classified into two main groups: those in which the spectrographic analysis is carried out on dry solid materials and those in which solutions of the materials are used.

PELLETTING TECHNIQUE

The study group gave first consideration to the dry method and a typical pelletting technique published previously[1] was taken as starting point for experimental work.

Table I

SUMMARY OF METHOD USED FOR PELLETTING TECHNIQUES

a	0·05 g slag 0·20 g Co_3O_4 5·0 g borax } Fused at 1000° C, cooled, crushed, to pass 150-mesh sieve
b	1·0 g powdered fusion mixture 2·0 g pure graphite } Mixed thoroughly
c	0·5 g graphite/fusion-mixture pressed into ¼-in. dia. pellet by load of 7000 lb
d	Pellet subjected to controlled intermittent a.c. or d.c. arc discharge to produce spectra

The first results obtained were not very successful, the calibration graphs showing a wide scatter of points. This was ascribed to:

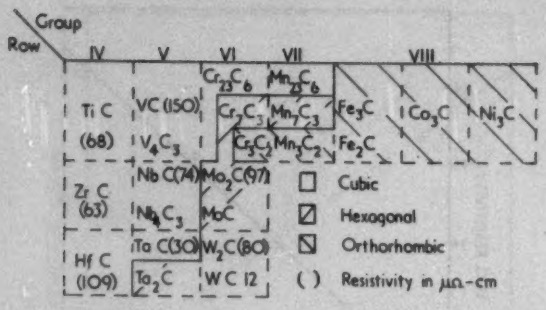
(i) Insufficient mixing of the powdered materials when preparing standard slags for calibration
(ii) Heterogeneity of the fused melt
(iii) Insufficient mixing of the powdered melt and the graphite
(iv) Fragility of pellets
(v) Use of non-homologous (unmatched) line pairs.

Further experiments showed that by the use of special mixing techniques the difficulties (i), (iii), and (iv) could be overcome, while detailed examination of many alternative spectrum lines enabled more closely matched line pairs to be used. It was not found possible to improve the heterogeneity of the fused melt. In spite of the general improvement in the technique however, good calibration graphs could not invariably be produced, and as the pelletting technique could not be carried out within 30 min, it was decided that other techniques would have to be considered.

TIPPING TECHNIQUE

Attention was drawn to the possibility of introducing the slag into the discharge by tipping the end of the graphite electrode with the fused slag–sodium-carbonate–borax mixture. Such a method was in routine use for the determination of alumina in silica bricks in one laboratory.[2] The procedure was

Paper MG/DD/217/57 of the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, received 11th November, 1957.



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The Spectrographic Analysis of Slags

By the B.I.S.R.A. Methods of Analysis Committee

SYNOPSIS

The report describes the investigation of a number of accepted methods of slag analysis, carried out to ascertain whether any of the methods could be modified to give results within 30 min and be reproducible to within ± 3%. Pelletting, tipping, dry powder, and solution techniques are examined, and among the variables studied attention is given to the making of the powdered samples, homogeneity of the fused melt, effect of the fusion mixture ratio, polarity of sample, and (in the case of solution techniques) the effect of electrode shape and preliminary treatment. None of the solid sample or powder techniques was satisfactory but a solution method was formulated which gave results most nearly conforming to the criteria adopted. Details of the recommended solution technique, together with examples of results obtained, are presented.

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Introduction

A STUDY GROUP WAS FORMED from the Spectrographic Analysis Sub-committee of the British Iron and Steel Research Association to investigate the analysis of steelmaking slags. Its purpose was to endeavour to formulate a method which would give the complete analysis of a slag with an accuracy of ± 3% in 30 min.

The constitution of the study group, which held its first meeting in May 1952, was: Mr. A. Argyle (Convenor from Jan. 1954), British Cast Iron Research Association; Mr. G. L. Mason (Convenor until Jan. 1954), formerly with United Steel Companies Ltd.; Mr. W. L. Dutton, Imperial Chemical Industries Ltd.; Mr. L. Gwilliam, United Steel Companies Ltd.; Mr. M. Z. de Lippa, Consett Iron Company Ltd.; Mr. S. Muir, Stewarts and Lloyds Ltd.; Mr. W. S. Sykes, Steel, Peech and Tozer; Mr. R. H. Tyas (Secretary), British Iron and Steel Research Association.

It was agreed that to develop a reliable method for the analysis of slags, refractories, ores, etc., the study group would examine other spectrographic methods available for the analysis of non-metallic materials when these were appropriate. Such methods can be classified into two main groups: those in which the spectrographic analysis is carried out on dry solid materials and those in which solutions of the materials are used.

PELLETTING TECHNIQUE

The study group gave first consideration to the dry method and a typical pelletting technique published previously[1] was taken as starting point for experimental work.

Table I

SUMMARY OF METHOD USED FOR PELLETTING TECHNIQUES

a	0·05 g slag 0·20 g Co_3O_4 5·0 g borax } Fused at 1000° C, cooled, crushed, to pass 150-mesh sieve
b	1·0 g powdered fusion mixture 2·0 g pure graphite } Mixed thoroughly
c	0·5 g graphite/fusion-mixture pressed into ½-in. dia. pellet by load of 7000 lb
d	Pellet subjected to controlled intermittent a.c. or d.c. arc discharge to produce spectra

The first results obtained were not very successful, the calibration graphs showing a wide scatter of points. This was ascribed to:

(i) Insufficient mixing of the powdered materials when preparing standard slags for calibration
(ii) Heterogeneity of the fused melt
(iii) Insufficient mixing of the powdered melt and the graphite
(iv) Fragility of pellets
(v) Use of non-homologous (unmatched) line pairs.

Further experiments showed that by the use of special mixing techniques the difficulties (i), (iii), and (iv) could be overcome, while detailed examination of many alternative spectrum lines enabled more closely matched line pairs to be used. It was not found possible to improve the heterogeneity of the fused melt. In spite of the general improvement in the technique however, good calibration graphs could not invariably be produced, and as the pelletting technique could not be carried out within 30 min, it was decided that other techniques would have to be considered.

TIPPING TECHNIQUE

Attention was drawn to the possibility of introducing the slag into the discharge by tipping the end of the graphite electrode with the fused slag–sodium-carbonate–borax mixture. Such a method was in routine use for the determination of alumina in silica bricks in one laboratory.[2] The procedure was

Paper MG/DD/217/57 of the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, received 11th November, 1957.

Table II
TYPICAL RESULTS FROM TIPPING TECHNIQUE

Slag No.	Method	CaO	SiO_2	MgO	MnO	FeO
1	Chemical	32·7	36·5	5·9	1·09	0·72
	Spectrographic Max.	34·3	38·0	6·0	1·30	3·1
	Spectrographic Min.	30·5	36·5	5·9	0·95	2·1
2	Chemical	34·3	5·3	4·45	8·9	42·6
	Spectrographic Max.	33·8	5·6	4·8	9·6	50·0
	Spectrographic Min.	32·5	4·9	4·2	8·4	40·0
3	Chemical	44·7	25·0	10·5	6·12	5·7
	Spectrographic Max.	50·0	26·2	10·7	6·6	8·9
	Spectrographic Min.	43·0	25·3	10·0	5·9	5·8
4	Chemical	49·9	10·0	7·8	4·52	19·6
	Spectrographic Max.	55·5	10·4	8·0	4·8	22·0
	Spectrographic Min.	47·0	9·9	7·6	4·2	21·0

tested and found to give better reproducibility and consistent calibration graphs.

0·05 g slag, 0·1 g cobalt oxide, 1·0 g sodium carbonate, and 0·5 g prefused borax were fused in an electric furnace, at a temperature of 1100–1150° C, for a minimum of 4 min. Graphite electrodes ¼ in. dia. × ¾ in. long were preheated to about 800° C and dipped into the fusion melt. The fused material adhered to the electrode forming a solid tip of even thickness. The tipped electrodes were then arced against a ¼-in. dia. graphite counter electrode with a flat surface, using an intermittent a.c. (4 A closed circuit) excitation.

Subsequent investigation of this method, however, revealed that drift of calibration curves could occur from day to day and that such curves would be useless for analysis purposes unless standards were included on every spectrographic plate used. It was considered that the curve drifts might be connected with the fact that only a small fraction of the fusion tip was being used up in producing the spectra. The use of smaller fusion tips was suggested and experiments were repeated using graphite electrodes which had been machined to a smaller size before tipping. The fusion tip thus obtained was completely volatilized during the discharge time of 30–40 s and spectra of suitable density were obtained. The results of the modified tipping techniques showed some improvement in reproducibility and decreased tendency for curve drift.

The figures quoted in Table II were obtained from nine single determinations of each constituent of each slag.

At this stage the overall reproducibility obtainable was ± 5–10%. This fell far short of the ± 3% aimed at, and it was decided that further improvement of the reproducibility could only be expected if more information was obtained on the homogeneity of the slag–sodium-carbonate–borax fusion. This problem was investigated spectrographically and chemically. The B.I.S.R.A. Chemistry Department expressed the view that segregation of calcium borate would occur in the fusion mixture used. Chemical evidence was produced, showing that the concentration of calcium compounds could be approximately 5·5% higher at the bottom than at the top of a fused melt. Confirmation of this was obtained by the spectrographic examination of several small portions of a melt: the results showed that variations of up to 30% of the concentration of calcium compounds can occur.

In view of these findings, the effect of varying the sodium-carbonate/borax ratio was investigated. Results showed that a certain minimum of borax was necessary for successful tipping of electrodes and that this could not be reduced sufficiently to prevent any segregation of calcium compounds. Consequently, improved reproducibility could not be obtained by this means.

As niobium pentoxide was used successfully in other spectrochemical determinations, it was suggested that its use as an internal standard in place of cobalt oxide might give improved reproducibility. Its use was studied at the same time as the effect of the borax concentration was investigated. Typical results are shown in Table IV. They illustrate an improvement in reproducibility, but the study group considered that better results were required for most analytical work.

Further experiments were carried out using various mixtures of borax, lithium carbonate, sodium carbonate, with cobalt and niobium as internal standards, but the results obtained showed no improvement. The values of coefficients of variation were inconsistent and ranged between 3·5% and 11·5%. This reproducibility was not considered satisfactory for routine slag control and the group decided to discontinue its investigation of the tipping technique.

'Dry-powder' methods were then examined; the results and conclusions are given below.

POWDER-SPARK METHOD

This method is described by Milbourn and Hartley.[3] The experimental details are:

Lower electrode: 10-mm dia. graphite cup, internal dia. ⅛ in., depth ¼ in., loosely filled with slag powder
Upper electrode: 10-mm dia. graphite rod, 80° conical tip

Excitation: Hilger uncontrolled condensed spark for 45 s across a 3-mm gap. No added inductance. It was observed that the slag powder was blown into the spark column rather violently, but only in some cases did any material remain in the cup after 45 s.

Five slags of widely differing compositions were treated in this way and the following values for coeffi-

Table III
VARIATION OF LOG INTENSITY RATIO OF CALCIUM/COBALT IN PORTIONS OF ONE FUSION

	Portion of Fusion No.					
	1	2	3	4	5	6
Five tips from each portion of fusion	0·175 0·250 0·250 0·290 0·255	0·245 0·225 0·330 0·275 0·250	0·290 0·245 0·240 0·300 0·235	0·310 0·325 0·300 0·340 0·340	0·318 0·320 0·330 0·355 0·315	0·395 0·335 0·390 0·385 0·320
Mean Value	0·244	0·265	0·262	0·323	0·320	0·365
Coefficient of Variation	±10%	±10%	± 9%	± 4%	± 5%	± 8%

cients of variation (calculated from 5 exposures using a hypothetical graph slope of unity) of logarithmic intensity ratios were obtained:

Line Pair	Coefficients of Variation* Slag 1	Slag 2	Slag 3	Slag 4	Slag 5
Ca 2006·9/Fe 3009·6	2·2	4·1	2·6	4·1	4·6
Si 2519·2/Fe 2518·1	2·4	—	17·9	4·9	11·0
Mn 2556·6/Fe 2560·3	2·0	2·8	1·8	2·5	2·3
Mg 2781·4/Fe 2788·1	5·3	2·2	1·4	6·2	5·0

The results showed that although good figures were obtained with one type of slag the reproducibility for other types was poor. Attempts to construct concentration calibration graphs were unsuccessful and consequently the group considered the method would be unsuitable for its purpose.

POWDER-ARC METHOD

Lower electrode: hollow graphite tube, through which the slag powder was fed
Upper electrode: graphite rod, conical tip
Excitation: 5·9 A d.c. arc, lower electrode positive, 4-mm arc gap.

Each sample had been heated to 450° C to remove adsorbed water or gases which might cause sputtering in the arc, and each sample was completely volatilized during arcing.

The results were very poor, as shown below:

Line Pair	Coefficient of Variation*
Al 2367/Fe 2364	47·0
Ca 2721/Fe 2724	13·8
Mg 2790/Fe 2781	9·4
Si 2987/Fe 2990	23·6
Mn 3079/Fe 3068	8·9

This method was ruled out for further investigation.

CARRIER-DISTILLATION METHODS

Several experiments were carried out using various mixtures of slag powder, borax, ammonium chloride, graphite, niobium oxide, and copper oxide in shallow graphite cups. The excitation was by means of a d.c. arc, and variation of electrode dimension, polarity, arc current, or pre-burn period did not produce any reproducible intensity ratios which could form the basis of a routine analytical procedure. Typical details are given below and the results are shown in Table V.

* calculated on a hypothetical graph slope of unity.

Table IV

EFFECT OF VARIATION OF BORAX/SODIUM CARBONATE RATIO ON THE REPRODUCIBILITY OF LOG INTENSITY RATIOS USING NIOBIUM AS INTERNAL STANDARD

Melt	Si 2519·2 Nb 3152·2		Ca 3006·9 Nb 3152·2		Fe 3057·5 Nb 3152·2	
1 g Na_2CO_3, 0·05 g slag, 0·03 g Nb_2O_5 plus	L.I.R.	C.V., %	L.I.R.	C.V., %	L.I.R.	C.V., %
0·15 g borax	0·126	± 11·0	0·185	± 6·0	0·118	± 4·0
0·20 g borax	0·077	± 4·7	0·090	± 4·0	0·127	± 3·0
0·30 g borax	0·067	± 6·5	0·072	± 4·0	0·111	± 2·5
0·40 g borax	0·054	± 5·0	0·104	± 4·5	0·110	± 2·5
0·50 g borax	0·026	± 4·5	0·126	± 5·0	0·114	± 2·5

Table V

REPRODUCIBILITY RESULTS FROM CARRIER DISTILLATION METHOD

Excitation Time, s	d.c. Arc Current, A	Sample Polarity	Coefficients of Variation* Ca/Si	Ca/Fe
60	3	negative	2·6	5·4
30	7	negative	6·9	4·7
60	10	positive	9·6	4·5

* Calculated from 5 or 6 exposures, using a hypothetical graph slope of unity

0·05 g slag mixed with 0·5 g NH_4Cl and 0·5 g powdered graphite
Sample electrode: ¼-in. graphite JM4B with a $\frac{1}{16}$-in. dia. hole drilled to a depth of ¼ in. with a $\frac{1}{32}$-in. wall
Counter electrode: ¼-in. graphite pointed to 120°
2-mm gap set with feeler gauge
B 10 plate, developing time 3 min
Sample electrode filled with the mixture.

Further tests, briefly described below, were made using different excitation conditions. 9-mm electrodes were drilled to a depth of 6 mm with a 6·5-mm dia. hole. These were filled with the sample of slag and sparked with the uncontrolled spark and varying inductance values from 0·015 to 0·250 mH, 120° pointed counter electrode. An inductance of 0·015 mH appeared to give the best spectrogram.

With a 2-mm gap, 0·015 mH inductance, and 2 min exposure time the coefficient of variation (calculated from 5 or 6 exposures using a hypothetical graph slope of unity) was:

Ca/Si 9·4% Ca/Fe 5·0%

Using 9-mm electrodes, as above, an a.c. arc was used for excitation. With a current of 2A (closed gap), 2-mm gap, 30-s exposure, 120° pointed counter electrode, the coefficient of variation was:

Ca/Fe 6·2% Ca/Si 21·5%

Under the same conditions as above, except that a flat counter electrode was used, the coefficient of variation was:

Ca/Fe 4·3% Ca/Si 6·7%

A mixer slag was tried under some of the above conditions, but in all cases it was blown out of the electrode and no spectra were obtained.

HIGH-CURRENT D.C. ARC METHOD

This method was based on one by Rozsa.[4] The experimental details used were:

Lower electrode: undercut graphite cup containing a fixed quantity of slag–graphite mixture
Upper electrode: graphite rod with conical tip
Excitation: complete volatilization by d.c. arc, 12 A in 4-mm gap.

These conditions were not identical with those given by Rozsa but represented the nearest approach that could be made at that time. The spectra were characterized by heavy spectrum background and self-reversal, and results were poor. By simple modification, these effects were reduced and the best reproducibility values obtained were as follows:

Table VI
LINE PAIR DETAILS

Element Line	Total E.P.	Int. Std. Line	Total E.P.	Index %
Mg II 2790·8	16·4	Cr II 2792·2*	18·3	3
Mg II 2790·8	16·4	Cr II 2792·2	18·3	10
Fe II 2755·7*	13·3	Cr II 2757·7*	12·6	39
Fe II 2755·7	13·3	Cr II 2757·7*	12·6	11
Al I 3092·7	4·0	Cr I 3053·9	5·0	7·5
Mn II 2949·2	12·8	Cr II 2867·6*	12·5	5
Mn II 2949·2	12·8	Cr II 2867·6	12·5	16·5
Si I 2881·5	5·1	Cr I 2991·8	5·1	11
Ca II 3179·3*	13·1	Cr II 3180·7*	13·1	27
Ca II 3706·0	12·5	Cr II 3421·3*	12·8	30
Ca II 3706·0	12·5	Cr II 3422·9	12·8	58

* = Filtered Spectrum

	Coefficient of Variation, %
MgO/SiO_2	6·0
FeO/SiO_2	4·0
CaO/SiO_2	10·0
Al_2O_3/SiO_2	7·0
MnO/SiO_2	8·0

These results were too poor to warrant further investigation.

HIGH-VOLTAGE A.C. ARC METHOD

The study group next considered a method put forward in a private communication. The experimental details were:

Lower electrode: thin-walled micro-crater type approx. ⅛ in. dia., ¼ in. deep, packed with slag–cupric-oxide–graphite mixture (1/9/20)
Upper electrode: 120° pointed graphite
Excitation: Complete volatilization by high voltage a.c. arc, 5000 V, 3 A.

Only one member of the group was able to adhere to the method in detail and the following results were obtained:

Line Pair	Coefficient of Variation, %
Ca 3158 : Cu 3063	4·15
Ca 3181 : Cu 3063	4·15
Si 2519 : Cu 2441	3·90
Fe 3059 : Cu 3063	3·28
Mn 2949 : Cu 3063	1·83
Mg 2779 : Cu 2441	7·30
Al 3082 : Cu 3063	5·30

The fluctuation of overall spectral density was small and the coefficients of variation compared favourably with those quoted in the original method.

The method, however, had two drawbacks. (*a*) Without the use of the vibrator specified in the original method approximately 45 min was required to ensure thorough mixing of the slag–cupric-oxide–graphite mixture by conventional means. (*b*) The high-voltage a.c. arc unit was not commonly available in spectrographic laboratories in the U.K.

In view of the specialized equipment required, no further work could be carried out on this method.

Although solid sample and powder techniques were sufficiently rapid methods of analysis, coefficients of variation of 3% or less were not generally obtained when they were used on a routine basis. Consequently the group decided to investigate the use of solution techniques.

SOLUTION TECHNIQUES

Methods already in use at Stewarts and Lloyds[5] and Consett Iron Co., which varied only in details of procedure, were proposed. After preliminary tests the former method was adopted for further investigation. This method is described below.

Preparation of the Sample Solution

0·2 g of sample is fused in a mixture of 1 g of sodium carbonate and 0·5 g prefused borax in a small platinum crucible. The fusion is carried out at about 1100° C and is held molten, after it has become quiet, for 2–3 min. After cooling slightly, the crucible and its contents are placed in a beaker containing 25 ml 20% (v/v) HNO_3 and a few drops of H_2O_2 (100 vol.). It is now warmed and stirred until extraction is complete, avoiding boiling. The stirring is important since any local concentration or neutralization may result in precipitation of silicon. In the extraction, hydrogen peroxide is added to prevent precipitation of manganese, the resulting effervescence assisting in stirring the solution.

After removing the crucible, 10 ml of the internal standard solution (potassium or sodium dichromate solution 1 ml ≡ 0·025 g chromium) are added and the volume adjusted to about 50 ml. The solutions are stable for at least 1 h but excitation is recommended immediately after their preparation.

Excitation of the Solution

The electrode shape used is a shallow saucer-shaped cup cut in the normal 6-mm dia. graphite electrode.[5] The more usual rounded cup shape may be used, but there is a danger that the walls may be chipped and solution lost during impregnation.

The prepared electrodes are rendered porous by heat-treatment in a silica dish in a closed muffle furnace at 900° C. When the rods reach the temperature of the furnace they are removed and cooled in air. (The outward appearance of the electrodes should be practically unaltered after this treatment).

Immediately before impregnation, the electrodes are presparked 30 s in order to warm the graphite. 0·05 ml of the sample solution is now added by micropipette and, if necessary, a current of warm air (from a hair dryer) is applied to the electrode to assist penetration of the solution. As soon as the solution has disappeared into the graphite, the spark is switched on and the exposure made. The conditions of excitation are given below.

Wavelength range	2600–4000 Å
Slit width	0·015 mm
Source of slit distance	35 cm
Source	a.c. condensed spark, uncontrolled
Added inductance	0·015 mH

Table VII
REPRODUCIBILITY TEST RESULTS BY STEWARTS AND LLOYDS' METHOD

Constituent	Approx. Content, %	Coefficient of Variation, %
SiO_2	25	3·0
CaO	44	1·7
MnO	5	1·9
MgO	10	1·8
FeO	5·5	2·1
Al_2O_3	3	3·2

Upper electrode	6 mm dia. JM4B graphite, pointed to 80° cone
Lower electrode	6 mm. dia. JM4B graphite, prepared as previously described
Spark gap	2 mm
Preburn	30 s before application of the solution
Volume of solution	0·05 ml
Optical filter	100 %/30 % transmission
Exposure	60 s
Photographic plate	Kodak B.10.

Interpretation of Spectra

For plate calibration, the iron line series method is used, the galvanometer readings being converted to *P*-transformation values. Graphs are prepared from standard slags using the line pairs detailed in Table VI.

Accuracy of the Method

A reproducibility test, carried out at Stewarts and Lloyds and based on 20 determinations, gave the results shown in Table VII.

Exploratory Tests

The first co-operative tests by the group gave inconclusive results, some members obtaining coefficients of variation of 2–3%, while other values were in the range 9–11%. Variable spectrum densities were obtained. This was thought to be due to the variable rate at which the slag solutions were absorbed by the graphite electrodes. Rapid absorption, 0·05 ml in less than 30 s, was regarded as undesirable as this gave rise to low spectrum intensities. Slow absorption, 0·05 ml in not less than 120 s, was not always practicable and not always associated with results of high reproducibility. In an attempt to obtain consistency in the rate of absorption of the solution by the electrodes it was decided to investigate more fully the effect of such factors as electrode undercutting, electrode heat-treatment, and pre-sparking.

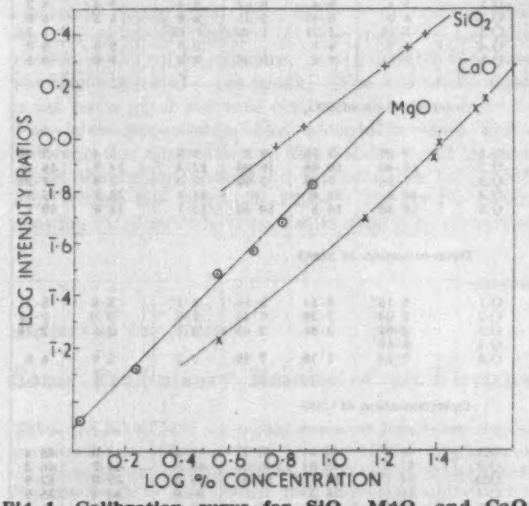

Fig. 1—Calibration curve for SiO_2, MgO, and CaO prepared from chemical analysis figures

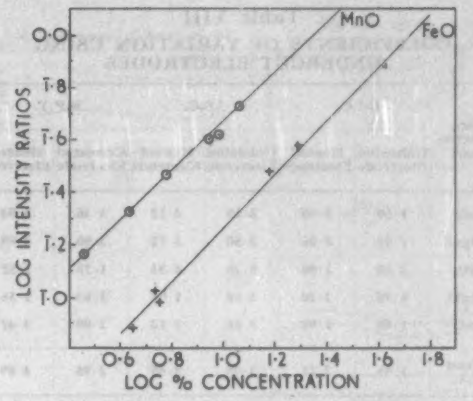

Fig. 2—Calibration curve for MnO and FeO prepared from chemical analysis figures

Electrode Undercutting

Following the initial tests carried out using cupped electrodes, the method of undercutting employed at the Consett Iron Company was investigated. The electrodes were undercut to give a platform 6·5 mm dia., 4 mm deep, and a pillar 2 mm dia., 3 mm deep. These electrodes did not at first show any marked improvement in reproducibility although one member obtained excellent results. It was observed in this case that the reproducibility of spectrum density was considerably better with undercut electrodes and this had in fact yielded lower coefficients of variation for all elements. The log-ratio for magnesium and calcium oxide showed a distinct variation with change of spectrum density. The heat-treatment and pre-sparking of the electrode, however, was obviously an important factor in promoting reproducible absorption rates and spectrum densities. Investigation of these factors was therefore continued using both straight and undercut electrodes.

Electrode Heat-treatment and Pre-sparking

By pre-sparking the electrodes the surface was cleaned and heated prior to the absorption of the solution. Pre-sparking was most important, however, with respect to the absorption of the sample, since it appeared that good reproducibility depended upon a constant rate of absorption being achieved. Members were divided on the best procedure to be adopted to obtain constant absorption because it was found that both the following methods gave equally satisfactory results.

(i) The electrodes were not heat-treated, a clamp having poor thermal contact was used, and the solution was applied to the electrodes while it still retained the heat generated by a pre-spark. The electrode was not allowed to cool and the speed in applying the solution was an essential factor in ensuring the recommended absorption rate

(ii) The electrodes were heat-treated and a clamp giving good electrical and thermal contact was used. In this case the heat from the pre-spark was quickly dissipated. The soaking rate of the applied solution was dependent on the previous heat-treatment of the electrodes.

Table VIII

COEFFICIENTS OF VARIATION USING UNDERCUT ELECTRODES

Slag Constituent	C.I.C.		U.S.C.		S.P.T.	
	Unheated Electrode	Heated Electrode	Unheated Electrode	Heated Electrode	Unheated Electrode	Heated Electrode
FeO	1·80	2·00	2·55	4·12	3·38	3·94
MgO	1·95	2·06	2·50	3·72	3·90	5·89
SiO_2	2·50	2·90	5·25	4·33	1·78	2·57
MnO	1·98	2·20	3·10	1·98	3·62	2·56
CaO	1·80	1·90	3·85	3·12	2·09	3·47
Mean C.V.	1·95	2·21	3·45	3·45	2·95	3·89

In order to obtain a constant rate of absorption, tests were also carried out to check the effect of exposure time, sparking off, etc., and the group strongly recommend that all the aforementioned factors be considered when adjusting operating conditions to achieve spectrograms of constant density.

Members of the group carried out final reproducibility tests using both straight and undercut electrodes. One or both of the alternative heat-treatment procedures was used, depending on the type of electrode holder. Although in some cases the undercut electrodes gave better reproducibility, not all members felt that the improvement justified the extra time involved in preparation.

Calibration graphs were produced from 7 slags, which had been analysed in several chemical laboratories to obtain reliable chemical figures. Figures for alumina contents have been omitted as agreement between chemical results was not altogether satisfactory. Typical calibration graphs are shown in Figs. 1 and 2.

The reproducibility tests based on 12–20 determinations were carried out on a slag with the composition given below and the results are summarized in Tables VIII and IX.

FeO	MgO	SiO_2	MnO	CaO	Al_2O_3
19·63	7·89	9·95	4·29	48·91	Not known

Analytical Accuracy

As the study group considered that the results of the final reproducibility tests were satisfactory, it was decided to carry out a co-operative investigation of the analytical accuracy of the recommended solution method. Table X shows the comparison of spectrographic analysis with the accepted chemical analyses. With minor modifications, the method has been successfully adapted to routine slag control on a direct-reading spectrograph.

SUMMARY OF RECOMMENDED PROCEDURE

Slag Fusion

0·2 g of −100 (B.S. 410) slag is fused carefully with 1·0 g anhydrous sodium carbonate and 0·5 g prefused borax. When effervescence has subsided, the melt is heated at 1000° C for 3–4 min.

Table IX

COEFFICIENTS OF VARIATION USING CUPPED ELECTRODES

Slag Constituent	Line Pair	S. & L.	S.P.T.	U.S.C.	C.I.C.	B.C.I.R.A.
FeO	Fe 2755·7 / Cr 2757·7	2·1	2·4	3·6	1·5	5·1
MgO	Mg 2790·8 / Cr 2792·2	1·8	5·5	3·3	2·5	3·9
SiO_2	Si 2881·5 / Cr 2991·8	3·0	3·4	6·8	2·9	4·5
MnO	Mn 2949·2 / Cr 2867·6	1·9	3·9	2·1	2·4	1·6
CaO	Ca 3179·3 / Cr 3180·7	1·7	2·5	2·7	2·0	4·1
Mean C.V.		2·1	3·5	3·7	2·3	3·8

Slag Solution

The cooled melt is extracted in 25 ml of 25% HNO_3 (warmed if necessary) to which a few spots of 100-vol. H_2O_2 have been added. During extraction the mixture is constantly stirred. When solution is complete

Table X

COMPARISON OF CHEMICAL AND SPECTROGRAPHIC ANALYSIS

Sample	Chemical Analysis	Spectrographic Analysis				
		U.S.C.	S.P.T.	S. & L.	B.C.I.R.A.	Mean
Determination of Iron						
Q.1	13·5	13·3	12·7	13·4	12·8	13·0
Q.2	5·4	5·39	4·65	5·2	4·6	4·96
Q.3	10·4	10·1	10·00	9·9	8·7	9·7
Q.4	0·86	...	...	...	...	...
Q.8	19·0	19·2	19·5	19·8	18·7	19·3
Determination of MgO						
Q.1	9·1	9·4	8·63	9·4	9·4	9·2
Q.2	6·0	6·35	5·35	6·0	6·2	6·0
Q.3	1·16	1·21	1·40	1·12	...	1·24
Q.4	5·9	6·0	...	5·9	5·8	5·9
Q.8	9·1	9·5	10·00	9·4	9·1	9·5
Determination of SiO_2						
Q.1	9·90	9·55	9·8	9·9	8·4	9·41
Q.2	16·40	16·05	16·00	17·3	14·9	16·06
Q.3	7·38	7·58	7·00	7·3	7·3	7·29
Q.4	33·0	31·6	...	31·1	35·7	32·8
Q.8	10·80	10·5	10·30	11·1	11·0	10·7
Determination of MnO						
Q.1	5·16	5·14	5·10	5·1	5·5	5·21
Q.2	7·04	7·20	7·26	7·0	7·0	7·11
Q.3	2·87	2·86	2·65	2·7	2·6	2·70
Q.4	0·69	...	...	...	...	...
Q.8	7·24	7·10	7·10	7·2	5·9	6·8
Determination of CaO						
Q.1	46·3	44·6	45·2	47·4	44·4	45·4
Q.2	47·3	45·8	46·5	48·0	44·7	46·2
Q.3	53·7	54·1	53·3	55·0	49·0	52·9
Q.4	36·1	36·3	...	36·8	34·6	35·9
Q.8	41·5	42·4	41·8	42·6	39·7	41·4

10 ml of internal standard solution (potassium dichromate, 1 ml ≡ 0·025 g Cr) is added and the whole is made up to 50 ml.

Electrodes

Lower—JM4B graphite 6·5 mm dia. either faced-off ends or saucer shaped to a depth of 1 mm (Fig. 3a) or undercut to give a platform 6·5 mm dia., 4 mm deep, and a pillar 2 mm dia., 3 mm deep (Fig. 3*b*).

Upper—JM4B graphite, conical tip 80°.

Heat-treatment of electrodes

It is important that the absorption rate of the solution into the graphite cups should be constant so that, on excitation, spectra of constant density are obtained. There are two satisfactory methods of reducing all the electrodes in a batch to a common state of porosity, as judged by the time taken for the solution to impregnate. (*a*) No prior heat-treatment other than that effected by pre-sparking. (*b*) The shaped electrodes are heated in a closed muffle furnace at approx. 900° C. When the electrodes attain the temperature of the muffle they are removed and allowed to cool in air. The appearance of the electrodes should be practically unaltered after the heat-treatment—heavy oxidation must be avoided.

A convenient procedure is to arrange the electrodes in a double row in a silica basin, cupped ends pointing outwards. The exact heating time will vary from laboratory to laboratory but under the conditions described will commonly be 5 min or less. The treated electrodes should be stored in a desiccator and should preferably be used within a few hours of their heat-treatment.

Pre-spark

30 s before the application of the solution.

Application of Solution

Alternative procedures: (*a*) For non-heat-treated electrodes, 0·05 ml of solution is applied to the lower electrode immediately after the pre-spark. The electrode clamp must have little or no cooling effect on the electrode itself. (*b*) For heat-treated electrodes, 0·05 ml of solution is applied to the lower electrode after the pre-spark. The electrode clamp must have good thermal contact with the electrode. For both procedures, the acceptable time period between the application of the solution and its complete absorption should be reproducible to ± 20% and within the range 30–120 s. Electrodes having soaking rates outside these limits should be discarded.

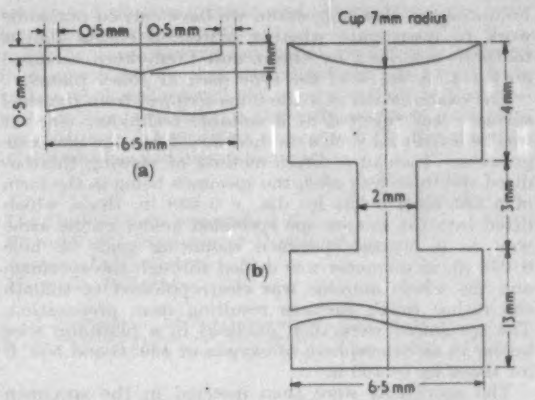

Fig. 3—(*a*) **Saucer-shaped electrode** (*b*) **Undercut electrode shape**

Excitation

Hilger-controlled condensed spark discharge, with an added inductance of 0·015 mH, across a 2-mm gap.

Exposure

60 s, commencing immediately the solution absorption is complete. A spectrographic stepped filter is a necessary accessory for this method.

Photographic Plate

Kodak B.10. Some convenient method of plate calibration is necessary.

Line Pairs Used

Details are given in Table VI.

Time of Operation

No attempts have been made to reduce the time of operation, and the recommended procedure takes 30–45 min to obtain a triplicate analysis of a slag sample.

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Letters to the Editor

Some Preliminary Results of an Electron Microscope Study of the Oxidation of Steels

THE OXIDATION of metal surfaces has been studied previously by the electron microscopical examination of oxide layers stripped from the surface of the metal. Recent work[1–3] has shown that direct examination of the oxidation process can now be made using the electron microscope.

Pfefferkorn[1] published electron micrographs of needle-like oxide growths on the surface of oxidized Fe, Ni, Cu, Zn, and Mo, and similar photographs were also shown by Gumz,[2] who suggested that the fouling of boilers by fly ash might be due to a process of physical entrapment of ash particles among the whisker growths.

Following up this suggestion, we have carried out some work to investigate whether oxidation effects similar to those described by Gumz and Pfefferkorn occurred on low-alloy steels of the type used in power plants.

The examination of oxide films stripped from the steel surfaces was rejected as a suitable technique, since it was believed that such a method would damage the oxide growths. Instead a direct method of viewing the oxidized specimen was used, the specimen being in the form of a flat disc, 0·094 in. dia. × 0·038 in. thick, which fitted into the microscope specimen holder in the same way as a normal specimen mounting grid. A hole 0·038 in. in diameter was drilled through the specimen and the whole annulus was electropolished to smooth the rather rough surfaces resulting from preparation. The specimens were then oxidized in a platinum wire holder in an atmosphere of oxygen at 450° C and 500° C for times up to 100 h.

The specimens were then inserted in the specimen holders and the inside surface of the central hole was examined in silhouette. Because of the thickness of the specimen, only oxide growths in one plane were sharply in focus and an attempt was made to overcome this difficulty by countersinking the central hole, thereby reducing the effective thickness of the edge to be examined. This method was not successful, however, as the whole specimen distorted so much that it no longer fitted into the specimen holder. Future improvements in technique will be directed towards the use of thin strip specimens, but when this work started, strip of the required steel qualities was not immediately available.

In all the steels examined, oxidation followed the same general sequences. At short times, a number of whisker growths of oxide were observed (Fig. 1), and as the time of oxidation increased the number and length of the whiskers increased. With further periods of oxidation, thin blades of oxides began to form (Fig. 2), whilst the number of whiskers decreased, and eventually these blades began to impinge at their bases to form compact layers of oxide. Still further oxidation resulted in the blades developing crystallographic surfaces (Fig. 3), to become very thin prisms. The marked thinness of the blades and prisms, as shown by their transparency to the electron beam, resulted in electron diffraction patterns being observed, which indicated that the oxides were Fe_2O_3. Eventually, after the longest times of oxidation investigated, there was a compact layer of oxide growths, the thickness of which was indeterminable; the surface of this layer consisted of many prismatic growths with only a few remaining whiskers.

Occasionally, small nodules were observed, spaced fairly evenly along the oxide whiskers (Fig. 4), similar to effects visible in the photographs shown by Gumz.[1] Whether these were the first stages of branching of the whiskers, or whether they were due to contamination, has not at present been ascertained.

Fig. 1—Whisker oxide growths formed during the early stages of oxidation × 10,000

Fig. 2—Whisker and blade oxide growths formed later in the oxidation process × 10,000

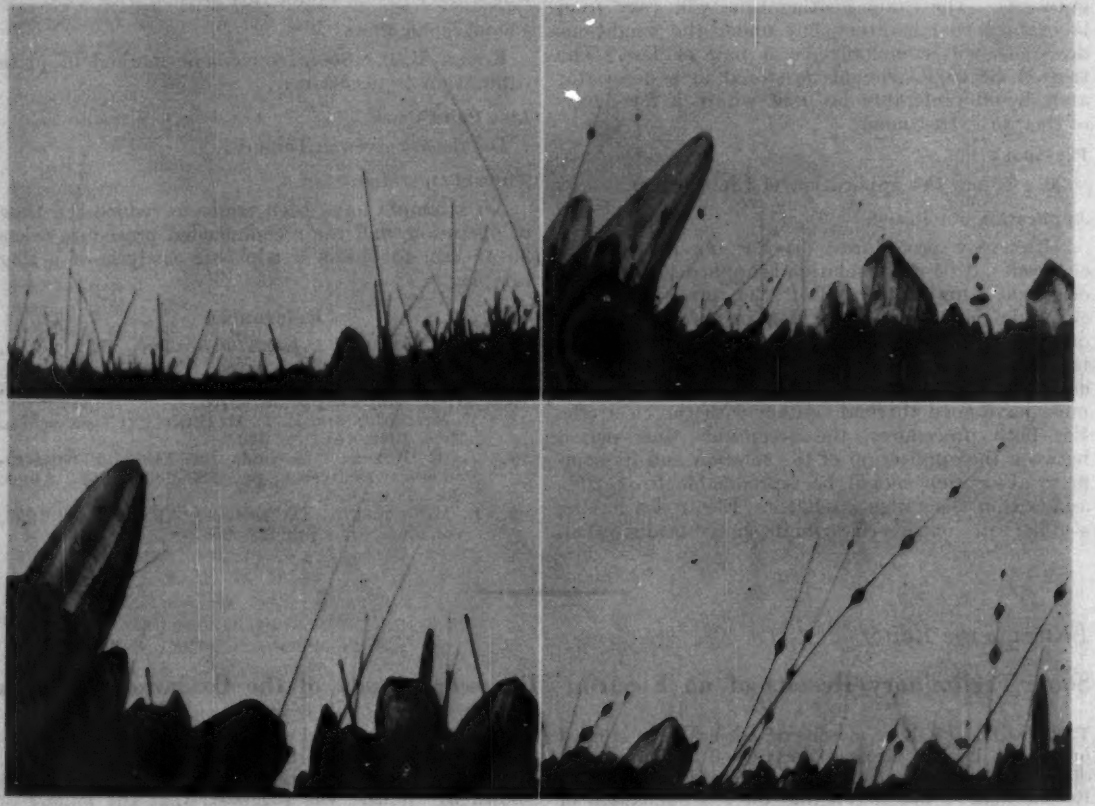

Fig. 3—Prismatic oxide growths × 10,000

Fig. 4—Nodules growing on oxide whiskers at fairly regular intervals × 10,000

As the temperature of oxidation was increased, so the various stages of the growth of the oxides occurred at shorter times, and in the early stages of whisker growth it was observed that, at any given time, the lengths of the whiskers on the various steels examined placed the oxidation resistance of these steels in the same order as conventional scaling tests.

The maximum number of whiskers or blades in the unit area of the surface is approximately 10^{10} per cm^2 in each steel, and this fact, together with the whisker-type growth of the oxides, suggests a dislocation mechanism for the nucleation and growth of the initial oxidation products.

The general results of this preliminary study, therefore, tend to confirm that the hypothesis suggested by Gumz[2] for boiler fouling is a possibility, as it would be quite easy for small particles of ash to be enmeshed among the whisker growths and thereby form the basis for large fouling deposits.

Furthermore, the mechanism of oxidation is revealed in a new light, in that oxidation appears to nucleate and grow at preferential places on a surface so that present theories, especially in the early stages of oxidation, may have to be modified to account for the presence of the whisker and prismatic growths.

A. M. EDWARDS
F. B. PICKERING

The United Steel Companies Ltd.,
Research and Development Department,
Swinden Laboratories,
Moorgate, Rotherham.

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Inverse Greyness in White Iron Castings Related to Delayed Cooling near the Surface

IN A RECENT PAPER by Thyberg[1] possible causes of inverse greyness in white cast iron (i.e. a surface rim with flake graphite in a white-iron casting) have been discussed with reference to temperature measurements carried out by the present writer. The results indicated that the cooling rate at the critical eutectic temperature range was lower just below the surface than it was in the interior of the casting. The occurrence of graphite near the surface is therefore related to the cooling rate. Since the phenomenon may be of general interest from the point of view of solidification of castings, some details of the experiments will be given here.

The cooling rate at different depths below the surface of a horizontally cast white-iron cylinder, 30 mm dia. × 15 cm long, was studied by recording the temperature indications from two Pt/Pt–Rh thermocouples. These were placed longitudinally in the cylinder at different distances from the surface, their junctions being located at the middle of the cylinder length. The couples were made of 0·35-mm wire, protected by capillary silica tubes of 0·40-mm bore and 0·90-mm o.d. The thermocouples fitted snugly in the tubes, ensuring the fastest possible rate of heat transfer from the surrounding metal. Bare junctions or a thin covering of Alundum cement instead of silica were found to have no advantage. The temperature was registered by connecting the two thermocouples alternately to a recorder capable of making a full movement from 0 to 3 mV in 0·8 s. The metal cast was a malleable iron with 2·6% C and 1·8% Si, melted in an induction furnace from raw material of commercial purity.

One of the thermocouples was usually located 1 mm below the surface and the other was placed at varying depths between 5 and 9 mm. The cooling curves obtained had the well known general shape showing the crystallization of austenite and the eutectic arrest. However, in the temperature range just above the eutectic arrest it was found that the cooling rate at the junction located adjacent to the surface of the specimen, contrary to what might be expected at first sight, was consistently less than in the interior. It should be pointed out that the specimens had a white structure throughout.

Similar cases of an ' inverse ' relationship between the cooling rates in the interior and in a surface zone can be found in Russell's simplified calculations of the cooling process in steel ingots[2] and also in Paschkis's studies on the solidification of castings by means of analogues.[3] Direct evidence of a lower cooling rate at the surface in certain temperature ranges during freezing can be derived from cooling curves in the work of Brandt, Bishop, and Pellini.[4] Adams has argued[4] that an increase in linear freezing rate at a late stage of solidification may be a normal process in castings. Some of the present writer's additional arguments on this point have already been elaborated by Thyberg.[1] In short, the required change in rate of cooling in a surface layer relative to the interior may be due to the fact that the initially rapid dissipation of heat from the surface zone outwards is slowed down considerably, owing to the rapid increase in the temperature of the surrounding mould, the rate of heat transfer from the interior being less affected by the rising mould temperature.

The demonstrated fact that the cooling rate in the temperature range which is critical for the crystallization of the eutectic was lower in the surface layer than inside may explain the occurrence of inverse greyness in white iron. If the composition of the iron and the cooling rate in the interior are well balanced so as to give a white structure verging on grey in the interior, the delay in cooling at the surface might well be thought to cause graphite to form instead of cementite. Inverse greyness should then be promoted by such factors which tend to give a rapid initial increase in mould temperature. The fact that a high pouring temperature of the iron favours inverse greyness is in accordance with this hypothesis. It is believed that other factors which have been found to influence the tendency towards inverse greyness do this indirectly. Inoculation from the mould, which has sometimes been considered responsible for inverse greyness, was found by the writer to be an inessential requirement, since a grey surface rim could be produced even in castings which were open to the air.

Since the first publication[1] of the findings reported here, indications of the same effect have also been found by Moore.[5] A full report of the present investigation has been published.[6]

This letter is published by permission of the Association for Metal Transforming, Mechanical and Electromechanical Engineering Industries, Stockholm, Sweden, with which the writer was associated at the time of this investigation. The writer is indebted to Professor E. Rudberg of the Institute for Metal Research for encouragement and the provision of equipment.

GUSTAF ÖSTBERG

Falu Kopparverk
Falun, Sweden

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Correspondence on the Paper—

Co-operative Trials on All-Basic Furnace Roofs*

By The All-Basic Furnace Sub-Committee

Dr. **W. F. Ford** (Department of Refractories Technology, Sheffield University) wrote: The summary of this paper states that the results indicate that volume stability at 1700° C and good refractoriness-under-load (R.u.L.) values or low creep rates are important properties in determining the life of a basic roof brick. These qualitative conclusions may be replaced by statistically significant relationships.

Neither the R.u.L. results nor the creep rates given in the paper have a sufficiently standard basis for statistical analysis, but the test for permanent linear change (P.L.C.) on re-heating at 1700° C yields directly comparable values. The P.L.C. results given by 30 basic bricks of known chemical analyses are obtainable from the data given in the paper; in those cases where 'ribs' and 'intermediates' were separately tested, the two P.L.C. values have been averaged, a procedure justified by the better correlation obtained. In Table 1 the results have been arranged for the seven brands of brick in the order of increasing shrinkage on reheating at 1700° C.

The text of the paper gives the following information. Consett stated that the green brick was equivalent to the blue and better than the yellow or the orange. Ijmuiden stated that the stripe green brick was best, the yellow was equal to the blue, and the green was better than the brown. Steel, Peech and Tozer stated that the blue was equal to the yellow and the green was better than the brown or the red.

Only Consett's finding that the blue brick gave as good a performance as the green brick is in conflict with the conclusion that the order in Table 1 is the order of merit of the basic bricks in service. It appears justifiable to conclude that the smaller the shrinkage in the reheat test at 1700° C, the better the performance of the brick, and it is therefore necessary to discover what fundamental property of the basic brick is measured by the P.L.C. test.

In the last column of Table 1 the average silica plus lime contents of the seven brands of bricks have been given. The appearance of a correlation between this flux content and the P.L.C. value is borne out by statistical analysis, the correlation coefficient being − 0·67, significant for the 30 samples at the 0·1% level. Elimination of the eight magnesite/chrome bricks yielded an even better correlation for this relationship, and the remaining analyses were confined to the 22 chrome/magnesite bricks, with the results shown in Table 2.

The table shows that 65% (8·03²) of the observed variations in the P.L.C. values are accountable for in terms of the silica, lime, and ferric oxide contents of the bricks. The higher the flux (silica plus lime) content, the greater is the tendency towards shrinkage on reheating, a result which might have been anticipated, since the flux content controls melt formation. The higher the ferric oxide content the greater the tendency towards expansion in the P.L.C. test, presumably because of oxidation–reduction processes, revealed by work on the phase relationships of iron-oxide-containing spinels.†

It has not been possible without a computer to include a fourth variable (apparent porosity) in the regression equation, but analysis shows that increasing porosity raised the reheat shrinkage. More significantly, the last two regression equations in Table 2 show that porosity is a dependent variable. Its value rises with silica content, falls very slightly as the lime content rises, and also falls with increasing iron oxide content. The operating mechanism in the first case is obviously the reaction-expansion of forsterite which opens up the brick structure as it is formed from magnesia and silica. The effect of iron oxide may possibly be ascribed to the fact that it is an index of the chrome ore content of the brick. The packing density might be expected to improve as the coarse chrome fraction increases over a limited range of grading.

The correlations obtained tend to confirm Rait's‡ published view that it is important to limit the silica and lime contents of chrome/magnesite bricks. .They also tend to confirm his hypothesis that the main cause of failure is flux penetration from the furnace atmosphere, for the higher the original flux content of the brick the sooner will flux concentration behind the working face reach a value high enough to cause shelling of the brick by reduction of its already low cohesive strength.

Table 1

AVERAGE P.L.C. VALUES AT 1700° C OF THE BASIC BRICKS

Type of Brick	Colour Code	P.L.C., %	SiO_2+CaO, %
Chrome/magnesite	Stripe green	0·0	4·7
Chrome/magnesite	Green	− 1·0	5·1
Magnesite/chrome	Orange	− 1·5	5·9
Magnesite/chrome	Yellow	− 2·0	6·4
Chrome/magnesite	Blue	− 2·2	5·4
Chrome/magnesite	Brown	− 4·6	7·5
Chrome/magnesite	Red	− 5·5	7·1

Table 2

STATISTICAL RELATIONSHIPS ON CHROME/MAGNESITE BRICKS

Regression Equations	Correlation Coefficient	Maximum Level of Significance, %
P.L.C. = 6·4 − 1·51 (S + C)	0·739	0·1
P.L.C. = 6·5 − 1·52S − 1·58C	0·744	0·1
P.L.C. = 0·72F − 1·54S − 1·63C − 1·5	0·803	0·1
P.L.C. = 13·3 − 0·74P	0·477	5·0
P = 19·0 + 0·70S − 0·01C	0·561	1·0
P = 32·8 − 0·92F	0·638	1·0

P.L.C.—percentage permanent linear change on reheating at 1700° C; P—percentage apparent porosity; S = %SiO_2; C = %CaO; F = %Fe_2O_3

* *J.I.S.I.*, 1957, vol. 185, pp. 304–328.

† R. G. Richards and J. White, *Trans. Brit. Ceram. Soc.*, 1954, vol. 53, pp. 233–270, 422–459.

‡ J. R. Rait, "Basic Refractories," p. 313: 1950, London, Iliffe and Sons Ltd.

AUTHORS' REPLY

Dr. **J. H. Chesters** (Chairman of the All-Basic Furnace Sub-Committee) wrote: We wish to congratulate Dr. Ford on his very helpful contribution to the discussion of the paper. The Sub-Committee has already changed its views on the primary causes of failure of all-basic furnace roofs several times and would certainly be willing to do so again given convincing evidence. We would agree that the correlation between low permanent linear change (P.L.C.) on reheating, or refractoriness-under-load, and roof life, may be due in fact to some other more fundamental factor, e.g. initial flux content. We have tested the correlations suggested by Dr. Ford by plotting certain additional data obtained since the paper was published, and we find that, although the general level of P.L.C. with these bricks was markedly lower, there is still a slight tendency for P.L.C. to increase with lime + silica content. No obvious correlation exists between the flux content and the roof life expressed in days, but an increase in roof life does appear to occur with decreasing P.L.C.

It must not, however, be forgotten that the P.L.C., and other properties (e.g. porosity) are affected by many other factors (e.g. moulding pressure and firing temperature). Furthermore, we have reason to believe that certain of the bricks mentioned by Dr. Ford as having a particularly low P.L.C. figure were also particularly hard-fired.

Our continued inability to explain roof life in terms of one or more properties of the unused brick was emphasized again in a recent trial, where two bricks having very similar lime + silica contents (6·3% and 5·8% respectively) were compared. The brick having the lower flux content gave the better performance, but the big improvement observed is far more likely to have been due to changes in other properties (e.g. grading and texture).

Correspondence on the Paper—

The Nature of Ageing of Binary Iron–Chromium Alloys around 500° C*

By R. O. Williams and H. W. Paxton

Messrs. **D. Wilkinson, G. T. Brown,** and **R. T. Allsop** (G.K.N. Group Research Laboratory) wrote: We should like to ask the authors for further information about the precise technique used in the X-ray analysis of specimens subsequent to deep etching.

It is suggested in the paper that Fig. 25 shows the (211) iron lines and the corresponding lines for the chromium-rich precipitate. Without knowing the geometry of the system and the radiation used to obtain this pattern, it is difficult to comment in detail. However, assuming that a back-reflection set-up was used with Cr radiation, the distances between the (211) iron line and any of the rather faint lines indicated by the word 'precipitate' in Fig. 25 seem excessive.

We would have expected that the (211) line of a b.c.c. structure containing 80% chromium would (considering the distance of the (211) iron line from the centre of the film) lie only a few millimetres outside the iron line rather than the centimetres actually shown. Unless the authors have used a technique of which we are unaware, it is difficult to see how the lines shown in Fig. 25 can be associated with a chromium–iron precipitate.

Since we are extremely interested in techniques for identifying this type of precipitate as a means of confirming embrittlement of the '475' type, we should appreciate details of any method which gives such a clear differentiation of the precipitate lines from those of iron.

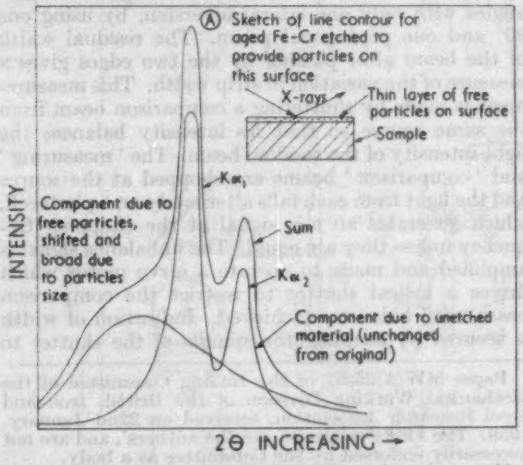
A Sketch of line contour for aged Fe-Cr etched to provide particles on this surface
X-rays
Thin layer of free particles on surface
Sample
Kα1
Component due to free particles, shifted and broad due to particles size
Sum
Kα2
Component due to unetched material (unchanged from original)
INTENSITY
2Θ INCREASING →

Fig. A—Line contour for aged Fe–Cr etched to provide particles on the surface

AUTHORS' REPLY

Dr. **R. O. Williams** (The Cincinnatti Milling Machine Company) wrote: Figure 25 in our paper is not entirely clear. The (211) line has two components: first, a sharp component, which is clearly seen, due to the unetched alloy, and secondly, a diffuse component superimposed and slightly shifted due to the precipitate. Figure *A* illustrates this better. Some of the other lines are due primarily to the precipitate, the (211) reflection for K_β and (200) for K_α.

With regard to techniques for showing the embrittled condition, it now seems certain that no X-ray technique on an unetched sample is capable of showing anything. However, when etching is carried out such that the iron-rich matrix is removed to leave chromium-rich particles on the surface, ordinary X-ray techniques show the particles; the lines due to the particles shift slightly owing to a different free lattice parameter and may be broad owing to particle size. My observations showed this method to work well most of the time, but the particles are apparently washed off the surface sometimes and are lost.

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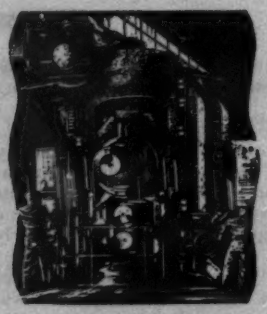
*J.I.S.I., 1957, vol. 185, pp. 358–374.



IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group

A Width Meter for Narrow Hot-rolled Strip

By C. Burns, B.Sc., and J. W. Stevens

SYNOPSIS

The instrument described measures the width of hot-rolled strip as it emerges from the mill. An accuracy of ± 0·005 in. was obtained, with a speed of response of 0·1 s. The readings are indicated on a high-speed paper recorder. The principle used is optical, and the methods adopted to maintain operation in the face of heavy atmospheric pollution by scale dust round the mill are described. The instrument is self-compensating against the transverse movements of the strip as it passes through its guide, and is very stable in the face of supply-voltage fluctuations and other factors which might otherwise upset its accuracy. It is suitable for the narrower sizes of strip, up to a limit of about 18 in. 1527

THE DEVELOPMENT of the width meter described arose from the demand for narrow strip rolled to close limits of width for forming into welded tube. Departures in either direction from the width limits can lead to a faulty weld. In the mills considered, the strip emerges at speeds of 400–600 ft/min at a temperature of about 900° C. A non-contact method is most desirable to avoid interference with the free running of the strip. The method must also include allowance for lateral movement of the strip, which cannot be closely constrained in its guides.

The instrument built operated in a Morgan mill, at the position where the strip is turned to travel on one edge in a narrow channel-shaped guide. Width could be measured to an accuracy of about ± 0·005 in. (0·13 mm) with a speed of response of 0·1 s corresponding to 2–3 ft travel of the strip. Vertical shake was usually less than $\frac{1}{8}$ in. and movement upwards out of the permitted limit was seldom encountered. The strip was always held in tension against one side of the guide which was curved, so error due to varying inclination of the strip to the measuring axis of the instrument was eliminated. Variations in strip width could be measured over ± $\frac{1}{8}$ in. with a tolerance to lateral movement of ± $\frac{1}{4}$ in. These two quantities, width variation and permissible displacement, are interchangeable, their sum being always equal to the width of the useful portion of the light beam used for measurement. These perfomance figures are for the instrument built and do not represent fundamental limitations.

To expedite the building of the experimental prototype, it was made to handle only one size of strip, the width most frequently rolled, about 4$\frac{1}{4}$ in. The modifications necessary to adapt the instrument for a variety of widths are mechanical, the optical working of the system being effectively unaltered for nominal widths up to about 1 ft greater than that for which the prototype was designed.

PRINCIPLE OF OPERATION

The instrument operates by passing a parallel beam of light, suitably reflected, past both edges of the strip, so that opposite sides of the beam are shuttered by opposite edges of the strip (Fig. 1). This is done by reflecting the beam through two right-angles with only one lateral inversion, by using one 90° and one pentagonal prism. The residual width of the beam after passing by the two edges gives a measure of the variation in strip width. This measurement is made by shuttering a comparison beam from the same source so that its intensity balances the light intensity of the residual beam. The ' measuring ' and ' comparison ' beams are chopped at the source and the light from each falls alternately on a photocell, which generates an a.c. signal at the chopping frequency unless they are equal. The unbalance signal is amplified and made to operate a servo motor which drives a helical shutter to restrict the comparison beam until balance is achieved. Indication of width is secured by coupling the spindle of the shutter to

Paper MW/A/35/57 of the Rolling Committee of the Mechanical Working Division of the British Iron and Steel Research Association, received on 22nd January, 1958. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

The authors are with the Instrument Section of the Physics Department of B.I.S.R.A.

a potentiometer which converts the reading of angular position into a voltage which operates a paper recorder with a high speed of response.

DETAILS OF CONSTRUCTION

For safety in the mill the whole instrument is built in a very substantial unit in an inverted **U**-shape (Figs. 2 and 3). The main unit is in a large box on one leg of the **U**, the other leg containing only the two prisms and their air-purging unit. The boxes are joined along the top by a deep and very rigid girder arrangement, as any angular displacement of one box with respect to another, being doubled by reflection and magnified by optical leverage, appears as a spurious change in indicated strip width. The electronic and main optical systems are built on both sides of a heavy panel bolted into the main box.

THE OPTICAL SYSTEM

A ' Pointolite ' lamp is used to provide a small intense source of light. Comparison and measuring beams are formed by similar collimator assemblies,

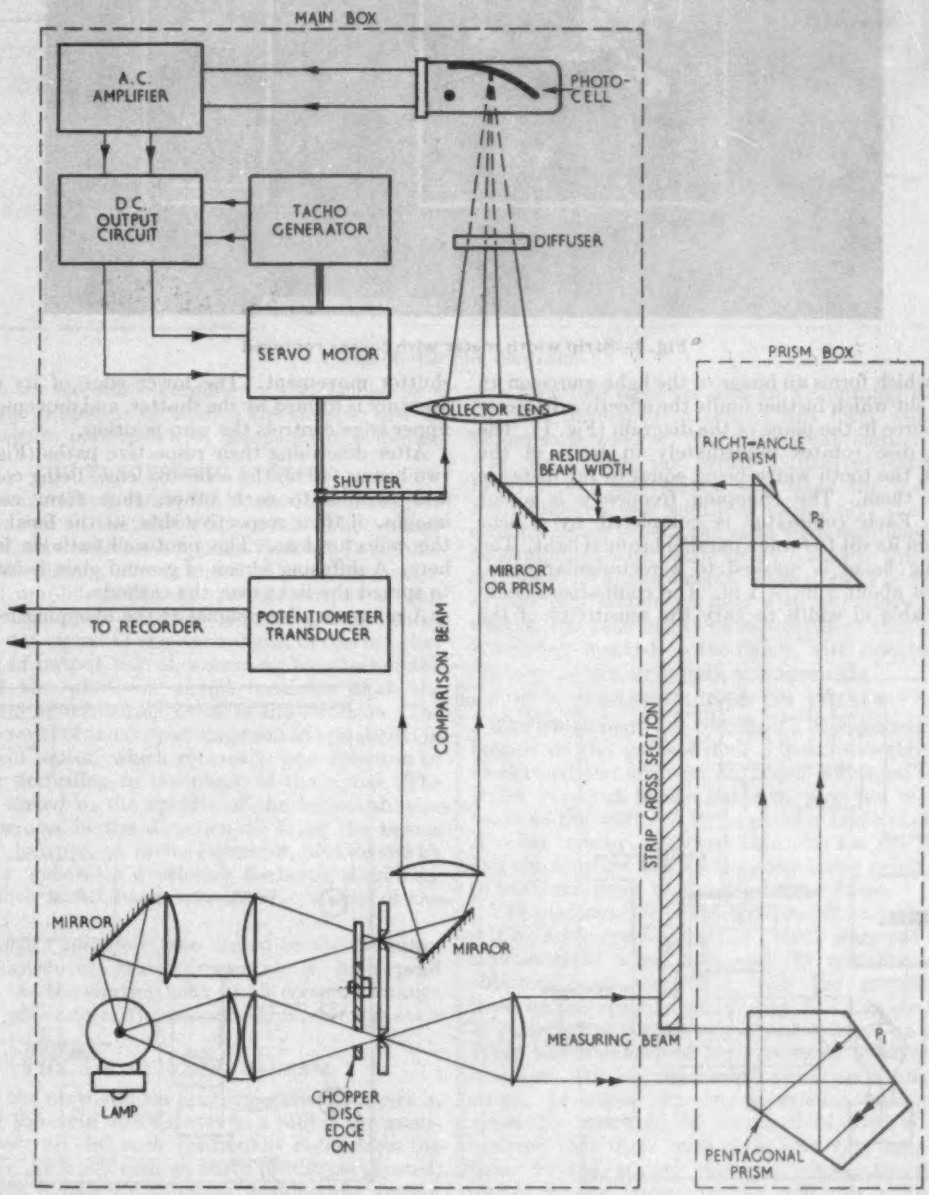


Fig. 1—Schematic diagram of width meter

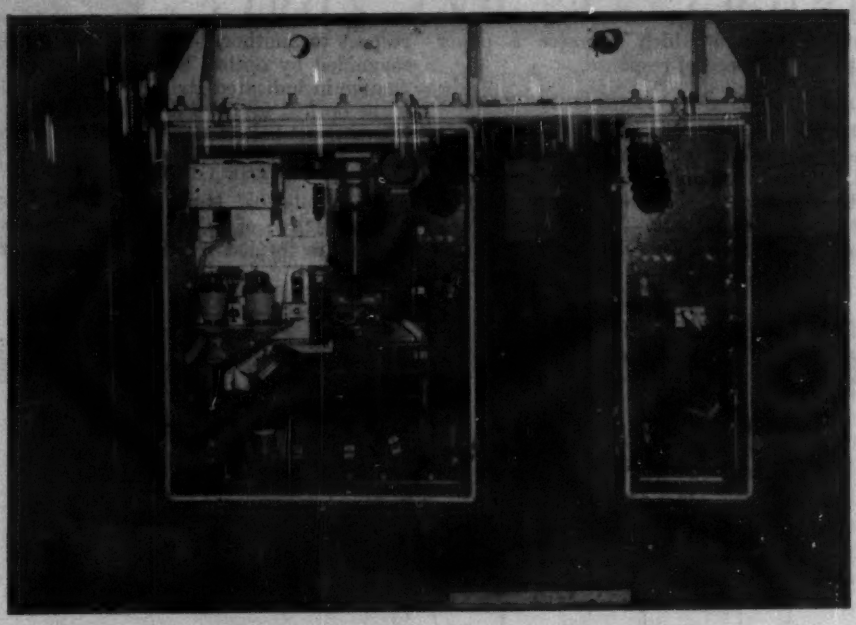


Fig. 2—Strip width meter with covers removed

each of which forms an image of the light source on an internal slit which further limits the effective diameter of the source in the plane of the diagram (Fig. 1). The chopper disc rotates immediately in front of the two slits, the tooth width being equal to the distance between them. The chopping frequency is about 300 c/s. Each collimator is completed by a lens focused on its slit to form a parallel beam of light. The measuring beam is masked to a rectangular cross-section of about $\frac{3}{4}$ in. × 1 in. The comparison beam is adjustable in width to vary the sensitivity of the shutter movement. The lower edge of its masking aperture is formed by the shutter, and movement of its upper edge controls the zero position.

After describing their respective paths (Fig. 1) the two beams fall on the collector lens. Being collimated and parallel to each other, they form coincident images, of their respective slits, at the focal point of the collector lens. The photocell cathode is placed here. A diffusing screen of ground glass is interposed to spread the light over the cathode.

A reference phase signal at the chopping frequency

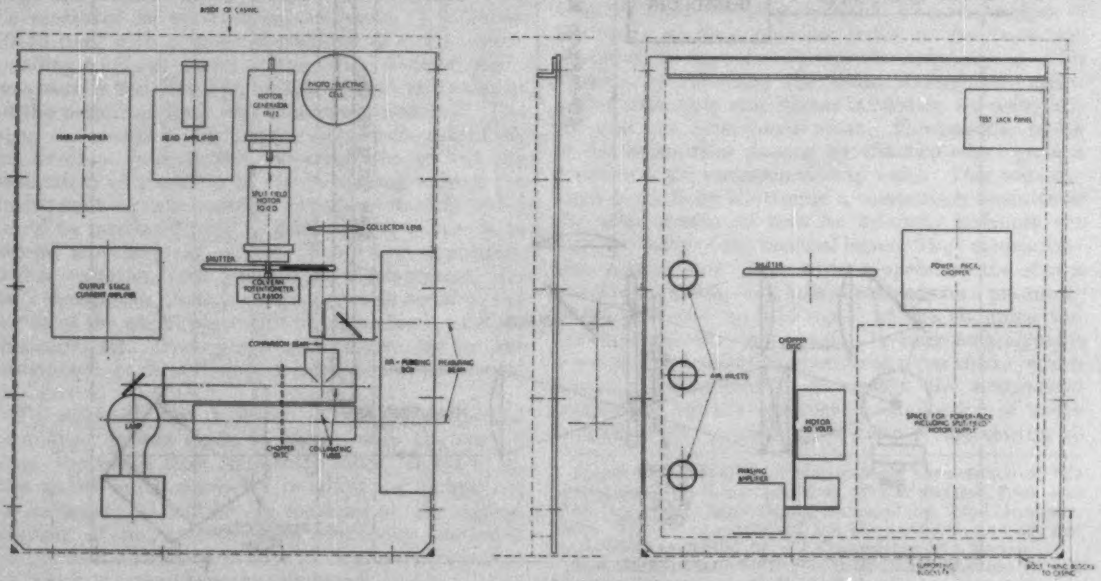


Fig. 3—Layout of instrument box

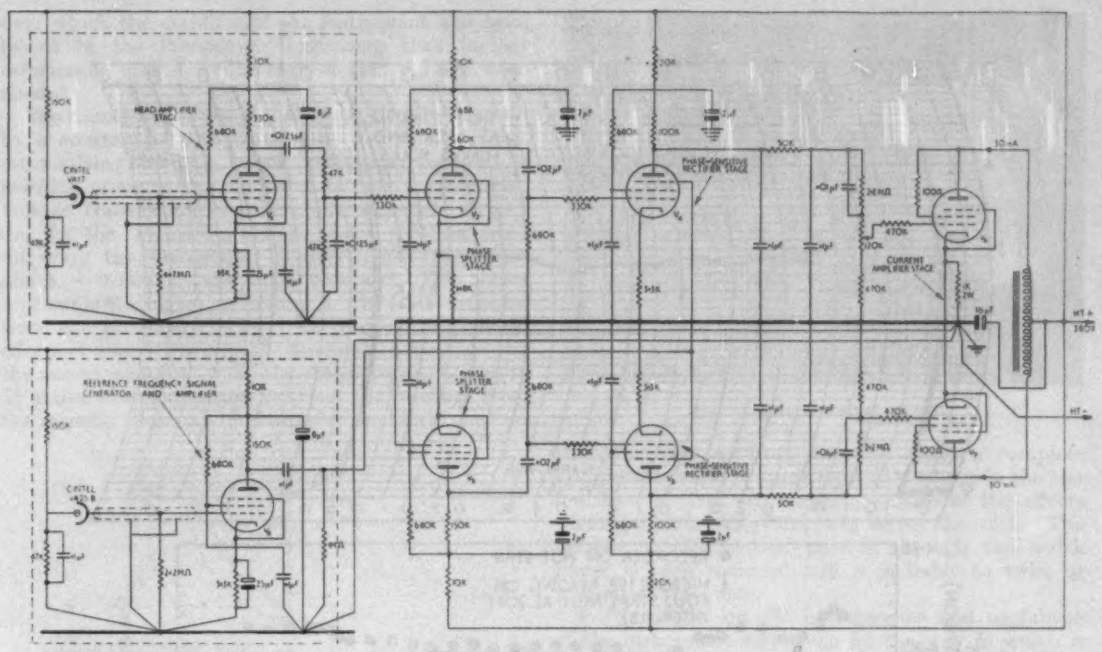


Fig. 4—Circuit diagram

for use in the electronic amplifier is also formed by a low-voltage lamp shining through the chopper disc on to a miniature photocell with independent amplifier.

THE ELECTRONIC SYSTEM

The photocell is a Cintel VA17 sensitive mainly to the upper end of the visible spectrum. The voltage across its load resistance is applied via a head amplifier to a phase-splitting circuit and a balanced two-stage push-pull amplifier (Fig. 4). At the output of this amplifier is a phase-sensitive rectifier circuit, which applies a d.c. signal to the control grid of one or other of a pair of output valves, according to whether the phase of the photocell signal indicates that the comparison or measuring beam is the stronger. The anode currents of the output stage run in opposition in a split field motor, which rotates in one direction or the other according to the phase of the signal. The motor is linked to the spindle of the helical shutter which operates in the direction to bring the beams back into balance. A tacho-generator, also driven by the motor, generates a velocity feedback stabilizing signal which is fed back into the d.c. stages of the amplifier.

The shutter spindle is also linked to the potentiometer transducer which operates a high-speed recorder. As the shutter helix has a constant change of radius with angle, the recorder shows a linear scale of width.

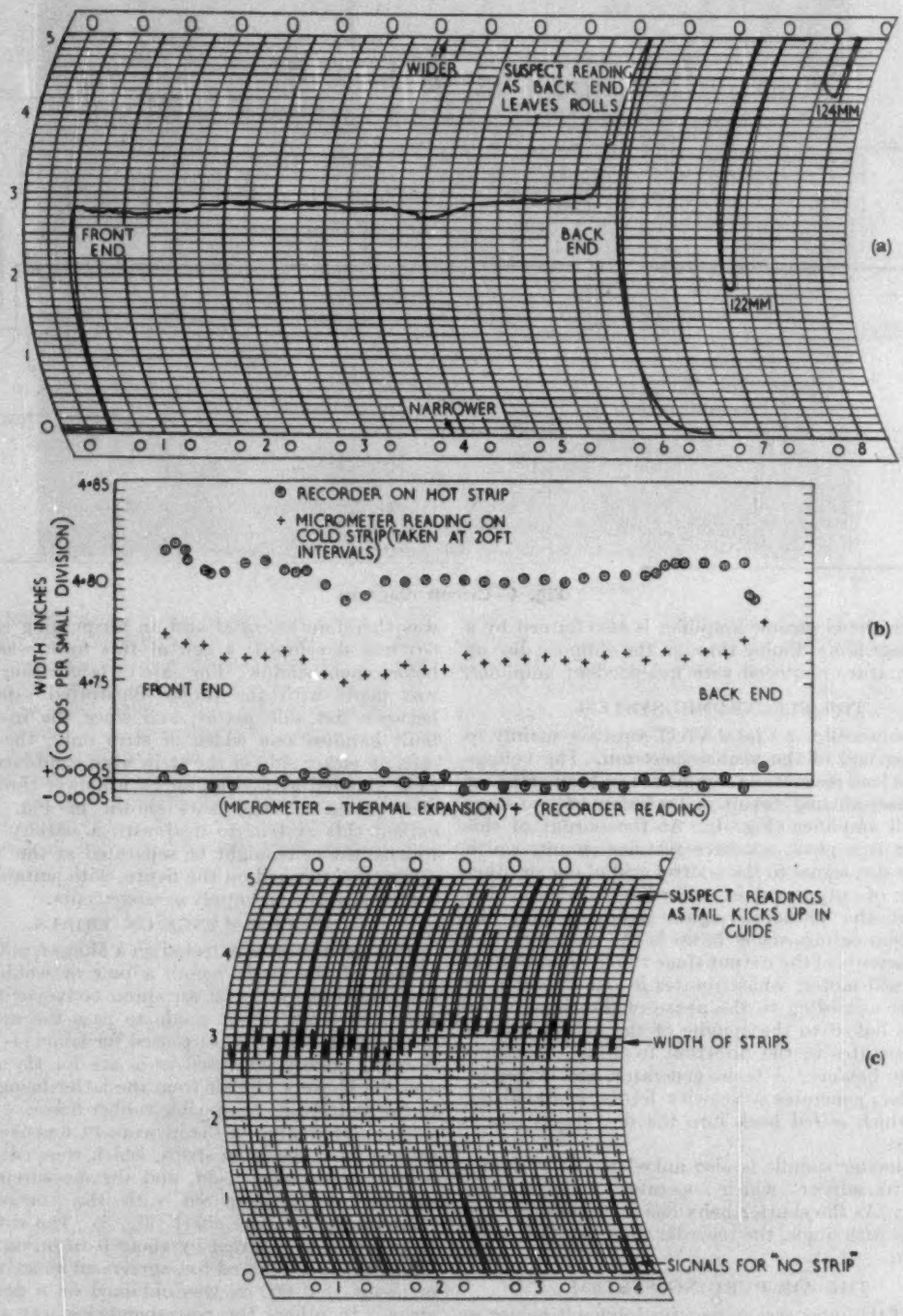
THE AIR-PURGING SYSTEM

One of the most serious practical difficulties met in operating the strip width meter in a mill is the quantity of finely divided scale continually rising from the hot strip. As trials with an early prototype showed, this rapidly fouled the windows, making the system inoperative. Some efficient method of repelling dust was therefore essential and an air-purging cell (Fig. 6*a*) was developed; a cell of this form was placed before each window. For ease of fabrication the cell was made with the profile illustrated sandwiched between flat side plates; and since the instrument built handled one width of strip only, the pair of cells on either side of the strip were combined in one rigid unit fed with clean air by a blower through the distribution arrangements shown in Fig. 6*b*. To extend this system to deal with a variety of strip widths, the cells might be separated at the 'plane of symmetry' marked on the figure, with suitable modifications to the air-supply arrangements.

PERFORMANCE ON TRIALS

The instrument was tested on a Morgan mill on one branch of the guide before a pair of wobbler rolls discharged the strip on an apron conveyor (Fig. 7). Holes were cut in the guide to pass the measuring beam at the width of strip used for trials (4·759 in.). A cellar nearby was used as a site for the recorder and the blowers, the air from the latter being carried to the instrument by flexible rubber hoses.

The performance of the instrument was checked by setting aside specimen strips, which were cut up and micrometered when cold, and the measurements so obtained were compared with the corresponding trace on the recorder chart (Fig. 5). The strip could be expected to contract by about 0·04 in. on cooling. When this was allowed for, agreement to an accuracy of about $\pm$ 0·005 in. was obtained on a number of strips. In others the correspondence was suddenly upset by amounts of about 0·01–0·02 in. It is believed that these were caused by very large variations in the supply voltages, especially the d.c. supply to the lamp. In the mill this voltage was subsequently found to fluctuate beyond the limits

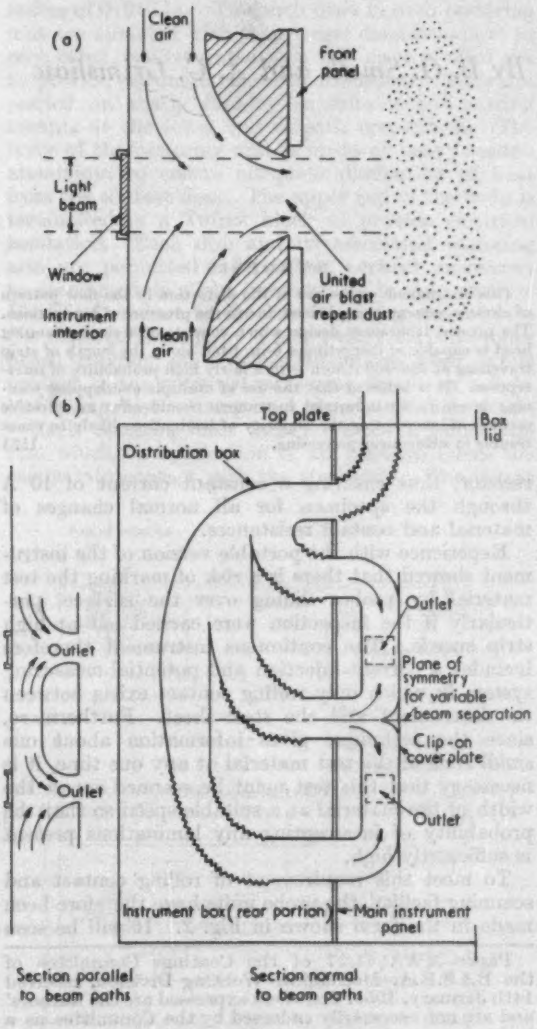


(*a*) Recorder traces of single strip at high recorder speed (18 in./min) and of calibration strips
(*b*) Analysis of recorder trace compared with micrometer measurements on cold strip
(*c*) Portion of all-night run at slow recorder speed, 18 in./h (0·3 in./min)

Fig. 5—Recorder traces and micrometer measurements of sample strips

over which the stability of the instrument had been tested in the laboratory, indicating that further safeguards against fluctuation of this voltage were needed.

The transducer to the recorder was already powered by a constant-voltage transformer to guard against error arising from d.c. supply voltage fluctuation. A rectifier power-pack, fed by a.c. from a constant-voltage transformer, was now introduced to supply d.c. for the 'Pointolite' lamp, and a recorder trace following the micrometer measurements to within about $\pm 0{\cdot}005$ in. was again obtained. This figure represents the highest accuracy to which the recorder trace can profitably be read, in view of the possible effects of dust or scale on the micrometer readings and the uncertain value of the thermal expansion. Figure 5*b* shows the comparison between the readings from the recorder chart and micrometer readings taken on



(*a*) Basic cell
(*b*) Air-purging arrangements

Fig. 6—Air purging

Fig. 7—Instrument on site

the cold strip at 20-ft intervals along a complete sample about 400 ft long. Optical readings in the last few feet of strip are suspect because of the effects when the back end of the strip leaves the rolls. The tension on the section passing through the width meter is then removed and it is liable to twist or rise out of the guide.

Further light on the performance and usefulness of the instrument was given by the way in which it illustrates consistent resemblance between successive strips, assumed to be due to variations in temperature along their length by uneven heating of the billets in the furnace. The instrument was also left running overnight with a slow recorder speed when the mill programme allowed this, and the readings it gave of strip width corresponded to the caliper-gauge checks taken by works staff; (these measurements are only accurate to about $\frac{1}{2}$ mm, i.e. $0{\cdot}02$ in.). On the contracted recorder scale, slow changes in rolled width over long periods were strikingly illustrated (Fig. 5*c*).

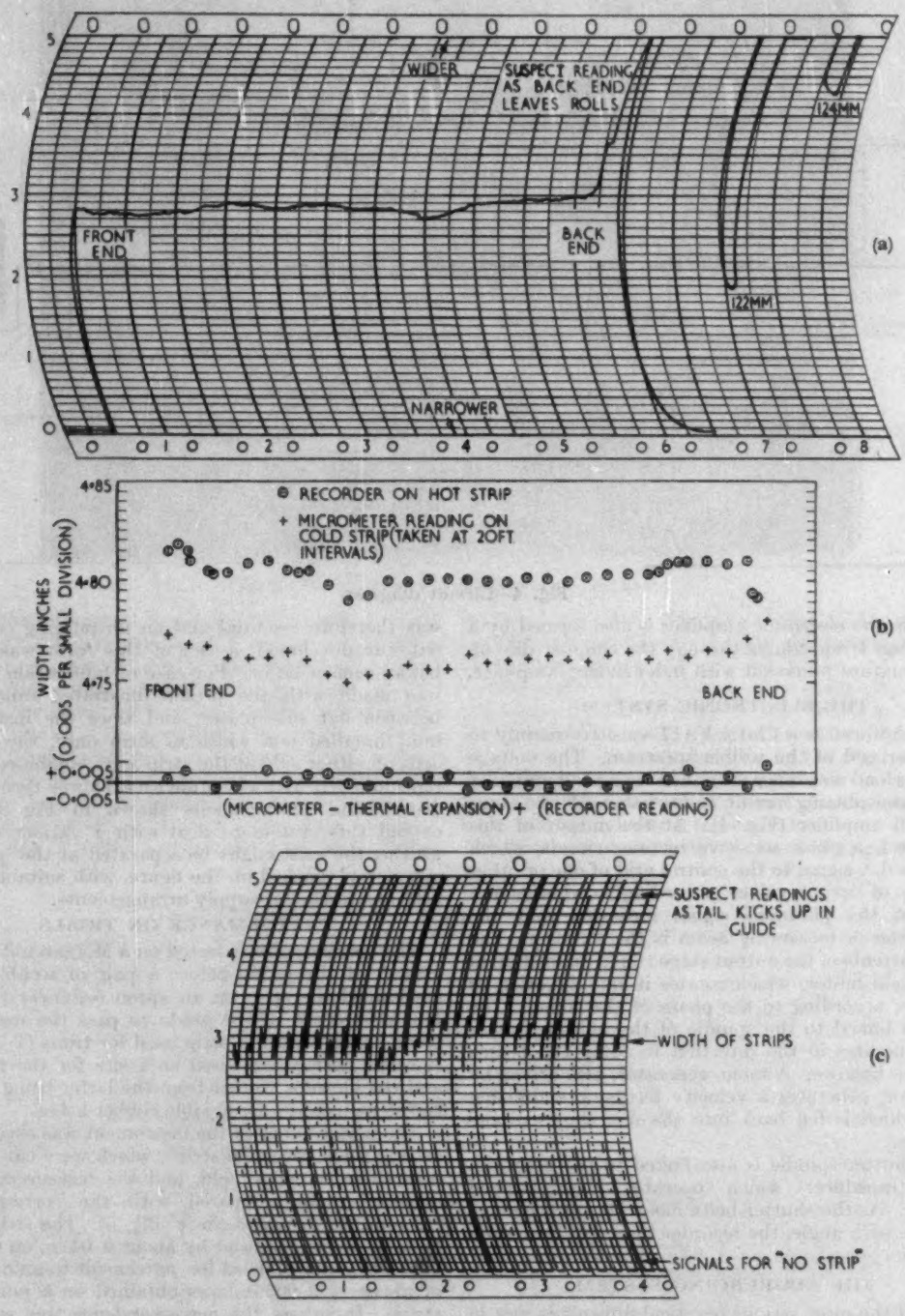
The air-purging arrangements kept the windows clean throughout the time on the mill. Runs of up to 24 h produced shifts of less than $0{\cdot}01$ in. in the recorder trace. A greater change than this was noted when the instrument was left standing unused for two days in comparatively clean surroundings.

CONCLUSION

The instrument can measure the width of strip to a few thousandths of an inch. Methods have been developed which enable it to do this on hot-rolled strip over prolonged periods of operation, in spite of the difficulties attending the operation on a mill. Purely mechanical modifications would allow the same performance to be applied to a variable width up to values considerably greater than that chosen for the prototype. The same method can be equally well applied to suitable cold objects.

Acknowledgments

The authors gratefully acknowledge the assistance in this project of Stewarts and Lloyds Ltd., who assisted in the construction of the instrument, undertook the mounting on a rolling mill, and co-operated in an extensive programme of trials. They also express their thanks to all members of B.I.S.R.A. staff who assisted in this project.



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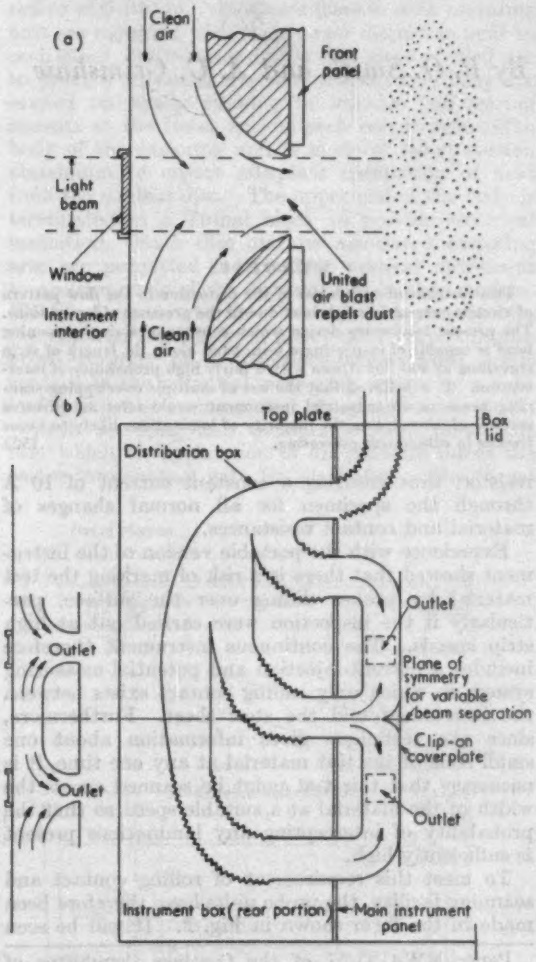

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Lamination Detector for the Continuous Inspection of Steel Strip

By B. O. Smith and A. G. Grimshaw

SYNOPSIS

This instrument makes use of the distortion in the flow pattern of electric current in steel sheet due to the presence of laminations. The present laboratory design which consists of a single scanning head is capable of inspecting a 6-in. band along the length of strip travelling at 300–500 ft/min with a fairly high probability of interception. It is believed that the use of multiple overlapping scanning heads in an industrial instrument would offer an effective method of intercepting the majority of laminations likely to cause trouble in subsequent processing. 1523

Introduction

THE DEFECTS of steel sheet known as laminations are the remains of cylindrical cavities in the parent ingot which by subsequent rolling may become thin cavities of relatively large area, parallel to the surface of the sheet and considerably extended in the direction of rolling. These defects, normally invisible at the surface, often show up when the material is pressed or deep-drawn.

One characteristic of laminations is that they can impede the flow of electric current and there is a measurable difference between the flow patterns for sound and laminated material. The method employed therefore is to pass current perpendicularly to the plane of the material and to measure the potential gradients near the point where the current is injected.

This technique was previously discussed in a report* on a manually operated portable instrument suitable for the inspection of stationary samples. Although static inspection can be of considerable value, extension of the method was clearly necessary to meet the need for continuous inspection of moving strip at a suitable point on a rolling line.

DESIGN OF THE INSTRUMENT

The basic circuit arrangement employed is shown in Fig. 1 and consists of a four-probe system. One pair of probes, on opposing faces of the test material, form part of a constant-current circuit, while the remaining two are connected to a suitable potential-measuring instrument. A rheostat R in the current circuit is sufficiently large to act as a 'swamp' resistor, thus ensuring a constant current of 10 A through the specimen for all normal changes of material and contact resistances.

Experience with the portable version of the instrument showed that there is a risk of marking the test material by probes sliding over the surface, particularly if the inspection were carried out at high strip speeds. The continuous instrument therefore includes a current-injection and potential-measuring system in which only rolling contact exists between the instrument and the steel sheet. Furthermore, since the technique gives information about one small zone of the test material at any one time, it is necessary that this test point be scanned across the width of the material at a suitable speed so that the probability of intercepting any laminations present is sufficiently high.

To meet this requirement of rolling contact and scanning facility, the probe units have therefore been made in the form shown in Fig. 2. It will be seen

* B. O. Smith, A. P. H. Jennings, and A. G. Grimshaw: *Brit. J. Appl. Phys.*, to be published.

Paper MW/C/41/57 of the Coatings Committee of the B.I.S.R.A. Mechanical Working Division, received 14th January, 1958. The views expressed are the authors' and are not necessarily endorsed by the Committee as a body.

Mr. Smith and Mr. Grimshaw are members of the Physics Department of B.I.S.R.A.

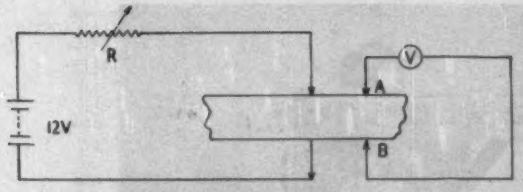


Fig. 1—Schematic circuit arrangement

that they are castor units with a limited up and down movement to accommodate vertical movement of the strip and an appreciable castoring angle to ensure that the plane of the contact element is appropriate for the combination of transverse scanning speed and longitudinal strip speed. The contact elements themselves are silver-steel discs in the form of truncated cones, the contact edge being rounded on a radius of 0·010 in. Two such discs in each castoring unit are mounted with their larger diameters next to each other, but separated by a thin piece of oiled silk to provide adequate electrical insulation. They are carried on shafts running in suitable ball-bearing mounts at the lower end of each castor arm. The body of the castoring unit is made of heavy-section aluminium to ensure adequate dissipation of heat from the contact disc. The upper end of the body is terminated in a Tufnol block to provide electrical insulation. Each disc and its associated castoring arm are permitted independent vertical movement to accommodate slight irregularities in strip surface. Electrical contact to the discs injecting current into the material is made by a heavy-duty carbon-bronze brush running on a phosphor-bronze bush, while contact to the potential-measuring disc is by a light leaf spring, also running on a phosphor-bronze bush.

Each castoring unit includes a small pneumatic ram which on application of air pressure forces the castor into contact with the steel strip. The thrust

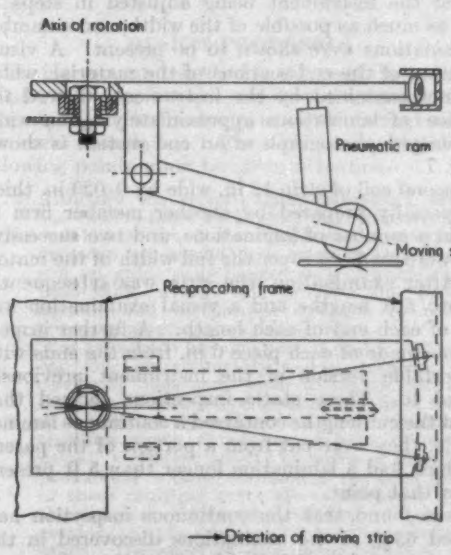


Fig. 2—Castor mounting of units

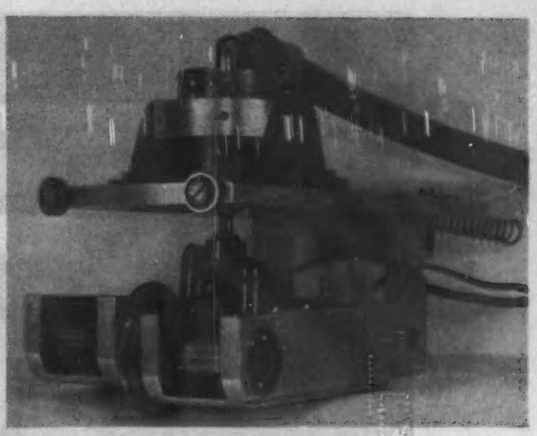


Fig. 3—Close-up of castor unit

from a single ram is transmitted to the two halves of each castoring unit by means of a Tufnol crosshead bar. Each pneumatic cylinder contains a return spring so that on removal of the air pressure each unit is retracted clear of the strip. This retraction is controlled by a simple electrical contact operating on the steel sheet, so preventing damage to the castor unit by overrunning the sides or ends of the sheet. Each complete test element consists of an upper and lower castor mounted on a common vertical axis one above and one below the test material. These castors are carried on a light reciprocating framework which is traversed backwards and forwards across the test material by a suitable crank linkage to an electric motor. In the present design, provision is made for a transverse scan of 6 in. Figure 3 is a photograph of one castor unit, while Fig. 4 shows a complete pair of castoring units mounted on a reciprocating framework for laboratory trials on a circular loop of steel.

The output from the potential discs, a signal of the order of millivolts, is fed via a d.c. amplifier to a pen recorder. In this way a continuous record of the presence of defects can be made as a strip of sheet passes the gauging point. In addition, the amplifier can be made to operate a suitable alarm indicator.

TRIALS OF THE INSTRUMENT

Alignment of Upper and Lower Units

It was necessary to establish the accuracy requirements for the alignment of the upper and lower castoring units since, if a high degree of precision was needed, it would be necessary to have a mechanical linkage between them. A number of tests were made on a sample of material 0·020 in. thick containing a ¼-in. wide lamination. Results are quoted in terms of angular misalignment between upper and lower units, although it must be appreciated that it is the linear displacement between these two units that controls the change in signal. On the prototype instrument a misalignment of 5° corresponds to a linear displacement between the units of about ¼ in. The results obtained on this first experiment are shown in Fig. 5. Figure 5*c* shows that on sound material the normal indication of about 1mV is

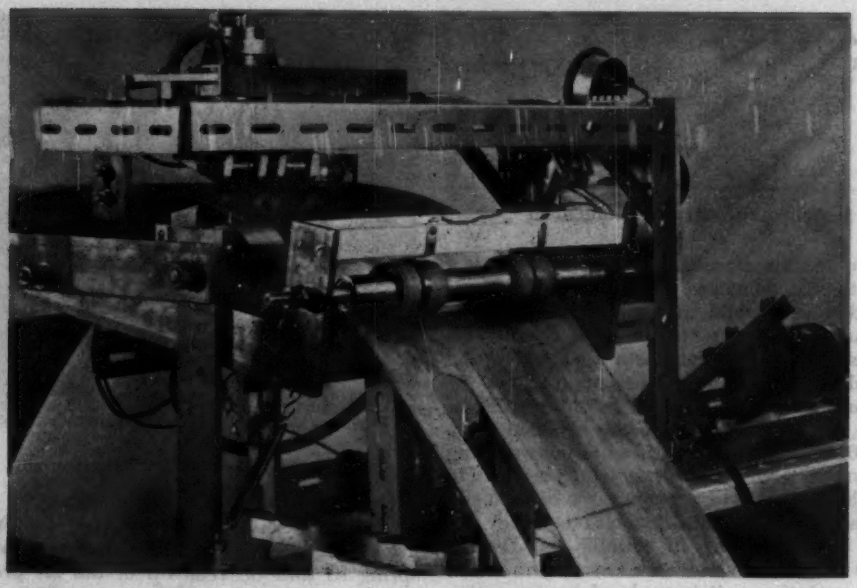


Fig. 4—General arrangement of experimental apparatus

obtained for misalignments of less than 7°, above which the signal starts rising to the level of 2–3 mV normally indicative of a lamination. When lamination is present in the test zone as shown in Fig. 5*a*, misalignments of at least 10° can be tolerated without loss of signal. Figure 5*b* shows the effect of a lamination to one side of the lower unit. If the upper unit is perfectly aligned this lamination could not be detected, although its presence is detected for a misalignment of about 5–10°. Figure 6 shows similar results on a specimen 0·050 in. thick containing a 2½-in. wide lamination and it will be seen that a considerably greater degree of misalignment can be tolerated. Further tests on a moving specimen travelling at 300 ft/min showed that the two castor units displaced at the maximum misalignment possible (approximately 60°) came into the permitted degree of misalignment by natural castoring action, while approximately 2–3 ft of material passed the gauging point and continued to run with not more than a degree or so of misalignment. It was therefore clear that a free-castoring action on the actual instrument would provide an adequate degree of alignment of the units.

Laboratory Tests on a Continuous Loop

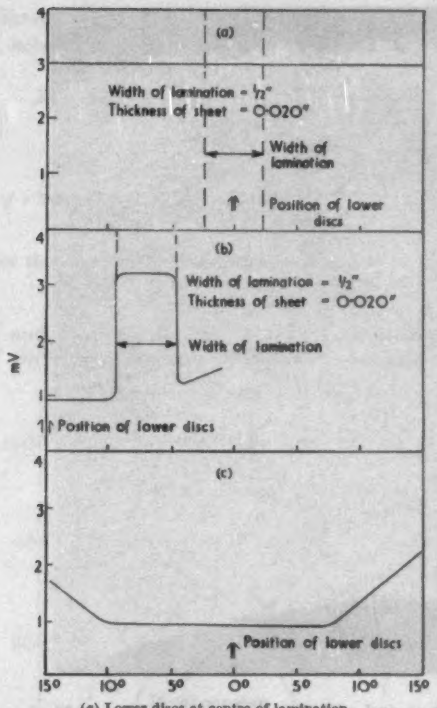
A circular loop of 12-in. wide test material was made up containing one 7-ft length of material known to be laminated. This loop running on a simple roller framework was used to investigate problems of brush design, disc wear, and automatic retraction. This experimental apparatus is also shown in Fig. 4. The present design of hardened silver-steel discs has proved satisfactory, as those at present in use on the instrument have now completed a year of fairly extensive trials including a 200-h continuous run and are still giving good service. It is therefore reasonable to assume that this design of disc should require little maintenance under works conditions.

Pilot Plant Trials

A number of trials on the instrument were carried out on a strip line at the B.I.S.R.A. South Wales Laboratories. In these trials strip was run past the instrument at about 300 ft/min. In a first trial a coil of cold-rolled strip 8 in. wide and 0·036 in. thick was supplied for test by a member firm. This strip was suspected of being laminated, but was not available for thorough destructive tests through its whole length. Several runs were made on this strip, the scan of the instrument being adjusted in steps to cover as much as possible of the width, and a number of laminations were shown to be present. A visual inspection of the end sections of the material, which were not examined by the instrument, showed the presence of laminations approximately $\frac{1}{32}$ in. wide. An enlarged photograph of an end section is shown in Fig. 7.

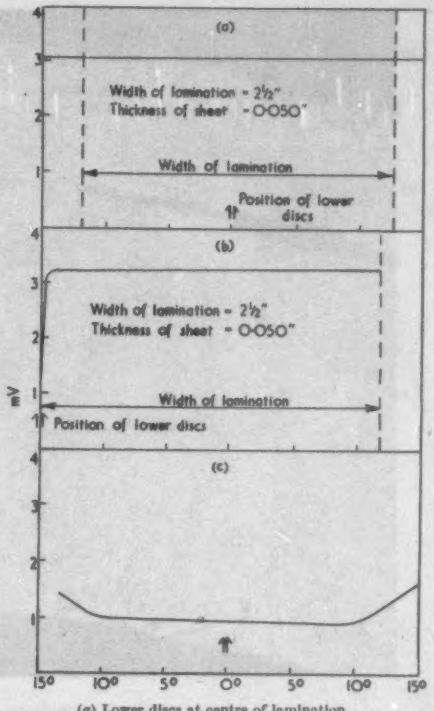
A second coil of strip 12 in. wide by 0·020 in. thick was specially prepared by another member firm to contain a number of laminations, and two successive scans were made to cover the full width of the material. After examination, the strip was subsequently cut into 5-ft lengths and a visual examination was made of each end of each length. A further inspection was made of each piece 6 in. from the ends with the portable version of the instrument previously referred to. These static inspections showed that 60% of the cut lengths contained a continuous lamination, i.e. they were cut from a portion of the parent coil which had a lamination longer than 5 ft present in it at that point.

It was found that the continuous inspection had detected 63% of the laminations discovered in the static scan. Of the 37% of laminations undetected,



(a) Lower discs at centre of lamination
(b) Lower discs at edge of lamination
(c) Readings on sound material

Fig. 5—Effects of misalignment of units: narrow lamination



(a) Lower discs at centre of lamination
(b) Lower discs at edge of lamination
(c) Readings on sound material

Fig. 6—Effects of misalignment of units: wide lamination

a proportion were known to be due to incomplete scanning of the parent strip since, owing to edge effects and drift of the strip in its guides, the two parallel-scanned areas did not always join along the centre line of the material and cover the whole of it.

DESIGN PROPOSALS

The instrument described in this paper is essentially a laboratory prototype which was constructed to gain experience in the design of an instrument suitable for works installation. For such an installation, the following points must be given attention.

(i) Although the reciprocating framework carrying the castors must be kept of light construction to enable high speed of reciprocation (approximately one scan per second) it is essential that it should run on guide rails housed in a suitable massive framework which will provide the necessary rigidity and mechanical strength to maintain efficient operation on a rolling line

(ii) This prototype has one pair of castor units which can give approximately a 6-in. traverse. It is obviously necessary that a works installation should be able to cover greater widths of material than this and the reciprocating framework should therefore carry a number of pairs of castoring units. Optimum results in terms of interception probability will be obtained if the scan patterns of these multiple units are interleaved, that is, the distance of scan of the framework should be greater than the centres of separation of successive units. The effect of such interleaving is shown in Fig. 8

(iii) *Scanning Rate*—It is obviously desirable that the transverse scanning speed should be as high as possible since in this way the probability of interception of a particular lamination is kept as high as possible. It is not considered practicable to scan at a higher rate than once per second for a 6-in. traverse. For a strip speed of 600 ft/min, one complete scan would thus be made while the material moves 10 ft, so that a 100% probability of interception of a lamination cannot be guaranteed if it is less than 10 ft long. An analysis of the scanning patterns traced on the material is given in the Appendix, the results being shown in Figs. 8 and 9.

CONCLUSIONS

In assessing the performance of the continuous lamination detector, one can only compare it against the manual detector, unless a complete point-to-point examination of the material is made to discover how many laminations were in fact present. This was not done in the experiments here described, but previous tests with the manual instrument had shown that more than 85% of laminations wider than ¼ in. can be detected. Present tests with the continuous model show that it can detect more than 60% of the laminations detected by the hand model.

It is fairly obvious that in developing an industrial instrument the performance of the prototype model can easily be improved by means of multiple overlapping scanning units, so that a much higher probability of interception and an efficiency approaching that of the hand model could be achieved. The

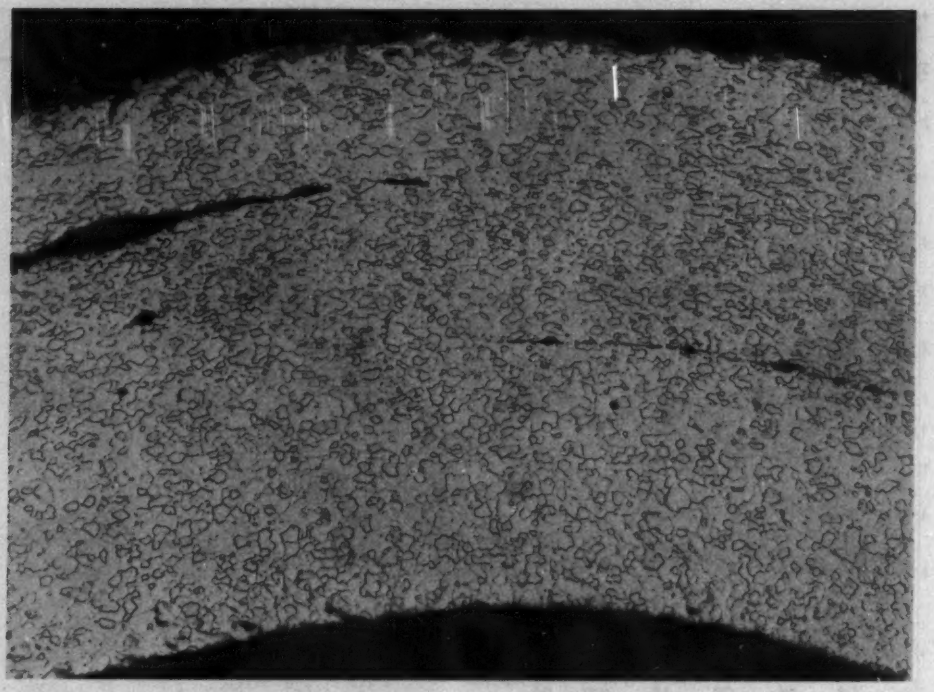


Fig. 7—Lamination present at end of coil × 95

instrument would thus offer a practical means of detecting the majority of laminations which at present escape detection and may cause trouble in subsequent processing.

Acknowledgments

The authors gratefully acknowledge the assistance given by J. B. and S. Lees Ltd., of West Bromwich, in providing a test coil of steel and for permission to use Fig. 7, and by Stewarts and Lloyds Ltd., of Corby, who prepared a special coil of laminated material for test purposes. They also gratefully acknowledge the assistance of their colleagues at B.I.S.R.A. South Wales Laboratory in carrying out the trials.

APPENDIX

Analysis of Scanning Pattern traced on Moving Material

To derive a mathematical expression for the scanning pattern, it is convenient to take a rectangular co-ordinate system on the moving material, the x-axis lying along one edge of the material and the y-axis being the initial line of scan, i.e. when $t = 0$. If it is assumed that the reciprocating linkage consists of a crank of length b rotating at a uniform angular speed ω, driving a connecting rod of length a, then the co-ordinates at time t of a point on the scanning carriage, such as the axis point of the castor arm, are

$$x = Vt$$
$$y = f + b\cos\omega t + \sqrt{(a^2 - b^2\sin^2\omega t)}$$

where V is the speed of the moving strip and f is a constant depending on the distance of the crank centre from the x-axis, and the distance between the end of the connecting rod and the reference point (xy).

The scanning point S is at the end of a castor arm of length d pivoting on the point (xy) at an angle ϕ to the y-axis given by $\tan\phi = \frac{dy}{dt}/V$.

Hence the co-ordinates (XY) of S are given by $X = x - d\cos\phi$, $Y = y - d\sin\phi$.

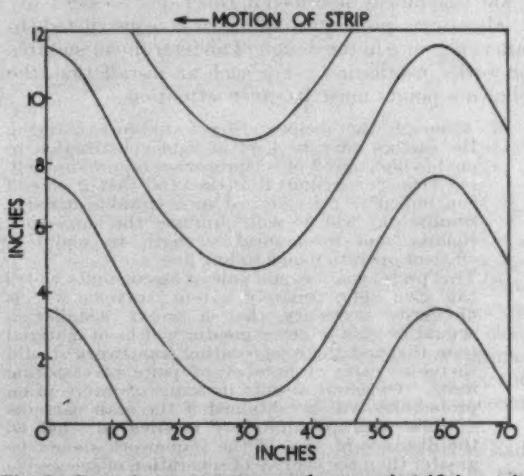


Fig. 8—Scanning patterns traced on moving 12-in. strip (multiple elements)

Eliminating ϕ, x, y, and $\frac{dy}{dt}$ from these equations, and substituting $G = \sqrt{(a^2 - b^2 \sin^2 \omega t)}$, we obtain

$$X = Vt - \frac{Vd}{\sqrt{\left\{V^2 + \omega^2 b^2 \sin^2 \omega t \left(1 + \frac{b \cos \omega t}{G}\right)^2\right\}}}$$

$$Y = f + b \cos \omega t + G + \frac{\omega d b \sin \omega t \left(1 + \frac{b \cos \omega t}{G}\right)}{\sqrt{\left\{V^2 + \omega^2 b^2 \sin^2 \omega t \left(\frac{1 + b \cos \omega t}{G}\right)^2\right\}}}$$

For the experimental model, $d = 5$ in. $V = 60$ in./s
$a = 8$ in. $\omega = 2\pi/s$
$b = 3$ in.

X and Y are plotted in Fig. 8 for a series of values of f corresponding to a number of scanning heads

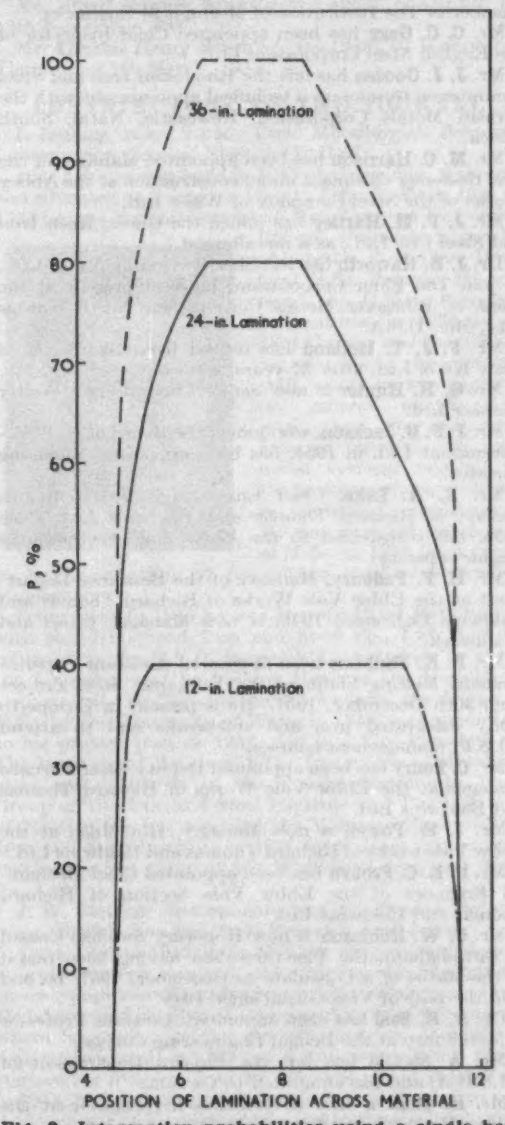


Fig. 9—Interception probabilities using a single head

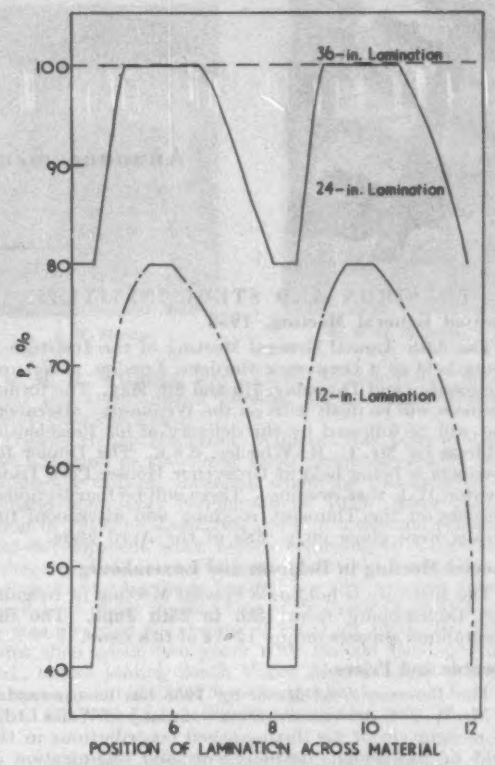


Fig. 10—Interception probabilities using multiple heads at 4-in. separation

4 in. apart covering the full width of 12-in. wide material.

From Fig. 8 it is now possible to estimate the probability P of intercepting a longitudinal lamination of length M lying along the line $y = h$. A single scanning pattern will make two intercepts of lengths m and n on this line during a complete cycle.

Hence P will be given by

$$(a)\ P = 100\left(1 - \frac{m + n - 2M}{m + n}\right)\% = \frac{200M}{m + n}\% \quad \text{For } M < m,\ M < n$$

$$(b)\ P = 100\left(1 - \frac{n - M}{m + n}\right)\% = 100\left(\frac{m + M}{m + n}\right)\% \quad \text{For } n > M > m$$

$$(c)\ P = 100\left(\frac{n + M}{m + n}\right)\% \quad \text{For } m > M > n$$

$$(d)\ P = 100\% \quad \text{For } M > m,\ M > n$$

Values for m and n applicable to the experimental model have been obtained from Fig. 8, using the single scan covering the range from 4·75 in. to 11·5 in. Values of P for three values of M are shown in Fig. 9.

A similar analysis has been employed in Fig. 10 to show corresponding values of P when multiple heads are employed.

N E W S

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

Annual General Meeting, 1958

The 89th Annual General Meeting of the Institute is being held at 4 Grosvenor Gardens, London, S.W.1, on Wednesday and Thursday, **7th and 8th May.** The formal business will be dealt with on the Wednesday afternoon, and will be followed by the delivery of his Presidential Address by Mr. C. R. Wheeler, C.B.E. The Dinner for Members is being held at Grosvenor House, Park Lane, London W.1, that evening. There will be four technical sessions on the Thursday morning and afternoon; full details were given on p. 389 of the April issue.

Special Meeting in Belgium and Luxembourg

The Institute is holding a Special Meeting in Belgium and Luxembourg from **18th to 28th June.** The full programme appears on pp. 12–14 of this issue.

Awards and Prizes

The *Bessemer Gold Medal* for 1958 has been awarded to Mr. W. F. CARTWRIGHT (Steel Company of Wales Ltd.), in recognition of his distinguished contributions in the field of the design, development, and organization of modern iron and steelworks and in the furtherance of steelworks engineering in all its branches.

The *Sir Robert Hadfield Medal* for 1958 has been awarded to Mr. W. C. F. HESSENBERG (B.I.S.R.A.), for a distinguished career in the British Iron and Steel Research Association and for his contribution to rolling mill research.

An *Andrew Carnegie Silver Medal* for 1957 has been awarded to Mr. S. W. K. SHAW (National Gas Turbine Establishment), for his paper, with Professor A. G. Quarrell, on "The Formation of Carbides in Low-carbon Chromium–Vanadium Steels at 700° C" (*Journal*, 1957, Jan., pp. 10–22).

Two *Ablett Prizes* for 1957 of £50 each have been awarded to Mr. C. E. H. MORRIS and Mr. R. N. DALE (Steel Company of Wales Ltd.) for their paper on "Planning the Conversion of a High-lift Slabbing Mill to a Universal Mill" (*Journal*, 1957, Apr., pp. 532–552).

A *Williams Prize* for 1957 of £100 has been awarded jointly to Mr. C. HOLDEN and Mr. A. D. ROBERTSON (United Steel Companies Ltd.) for their paper (with Dr. J. H. Chesters, who was not eligible for an award) on "Protection of Refractories by Moving Air Curtains" (*Journal*, 1957, Feb., pp. 177–200).

NEWS OF MEMBERS

Mr. **J. S. Blair** is now Manager (Coke and Iron) at the Ebbw Vale works of Richard Thomas and Baldwins Ltd.

Mr. **P. H. Bowker** has left the English Electric Co., Ltd., to join the staff of the Metallurgy Department of the College of Aeronautics, Cranfield.

Dr. **H. H. Burton,** C.B.E., has retired from executive duties with the English Steel Corporation Ltd., but remains on the Board.

Mr. **J. A. Cameron** has left the English Electric Co., Ltd., to join J. B. and S. Lees Ltd. as Chief Metallurgist.

Mr. **C. G. Davies,** formerly Assistant Works Superintendent (Iron and Steel), at the Ebbw Vale works of Richard Thomas and Baldwins Ltd., has been appointed Works Manager.

Mr. **A. T. Easterbrook** has been elected an Associate Member of The Institution of Mechanical Engineers.

Mr. **C. C. Gegg** has been appointed Chief Inspector of the English Steel Corporation Ltd.

Mr. **J. J. Goosen** has left the Rhodesian Iron and Steel Commission to take up a technical appointment with the African Metals Corporation, Newcastle, Natal, South Africa.

Mr. **M. C. Harrison** has been appointed Manager of the new Bessemer steelplant under construction at the Abbey Works of the Steel Company of Wales Ltd.

Mr. **J. F. M. Hartley** has joined the Guest, Keen Iron and Steel Co., Ltd., as a metallurgist.

Dr. **J. B. Haworth** has left Sherritt Gordon Mines Ltd., to join The Fluor Corporation; he is at present at the plant of Whitaker Metals Corporation, North Kansas City, Mo., U.S.A.

Mr. **F. J. T. Holland** has retired from the Board of Blaw Knox Ltd. after 37 years' service.

Mr. **G. H. Hunter** is now Senior Chemist with Walter Spencer Ltd.

Mr. **J. F. B. Jackson,** who joined the Board of A. P. V.–Paramount Ltd. in 1954, has been appointed Managing Director.

Mr. **R. A. Lake,** Chief Engineer of the Redbourn Section of Richard Thomas and Baldwins Ltd. since 1954, has transferred to the Ebbw Vale Section in a similar capacity.

Mr. **H. F. Padbury,** Manager of the Bessemer Department at the Ebbw Vale Works of Richard Thomas and Baldwins Ltd. since 1945, is now Manager (Steel and Brickwork).

Mr. **P. K. Paul** has been appointed Assistant Superintendent, Melting Shop, of the Durgapur Steel Project from 30th December, 1957. He is present in Europe to study integrated iron and steelworks and to attend B.I.S.F. management courses.

Mr. **C. Penry** has been appointed Deputy Blast Furnace Manager at the Ebbw Vale Works of Richard Thomas and Baldwins Ltd.

Mr. **J. H. Powell** is now Manager, Hot Mills, at the Ebbw Vale works of Richard Thomas and Baldwins Ltd.

Mr. **F. E. C. Probyn** has been appointed Chief Mechanical Engineer of the Ebbw Vale Section of Richard Thomas and Baldwins Ltd.

Mr. **C. W. Robinson** is now Honorary Swedish Consul in Birmingham, the Vice-Consulate having been raised to the status of a Consulate in December, 1957; he had held the post of Vice-Consul since 1948.

Dr. **A. K. Seal** has been appointed Assistant Professor of Metallurgy at the Bengal Engineering College.

Mr. **A. Sigalla** has left the Physics Department of B.I.S.R.A. and has emigrated to Canada.

Mr. **E. Stein** is now a Research Investigator at the Fulmer Research Institute, Stoke Poges.

Mr. **L. G. Stock** has become Assistant Works Manager at the Ebbw Vale works of Richard Thomas and Baldwins Ltd.

Dr. **P. H. Sykes** has been elected Chairman of the Low Temperature Group of the Physical Society.

Mr. **P. Truscott** is now Assistant Manager of the Bessemer plant being built at the Abbey Works of the Steel Company of Wales Ltd.

Mr. **E. H. Watson** has been appointed Works Metallurgist, Heavy Forgings, of English Steel Forge and Engineering Corporation Ltd.

Obituary

The Rt. Hon. Lord **Airedale of Gledhow** (*Honorary Vice-President; elected* 1906), of London, on 20th March, 1958.

Mr. **Ernest Leslie Dean** (*elected* 1953), of Rowley Regis, Staffordshire, in October, 1957.

Mr. **Albert Edward King** (*elected* 1953), of Cardiff, on 13th November, 1957.

Mr. **Thomas Henry Reece** (*elected* 1953), of Walton-on-Thames, on 7th March, 1958.

CONTRIBUTORS TO THE JOURNAL

I. Jenkins, D.SC., F.I.M.—Chief Metallurgist, Research Laboratories, General Electric Co., Ltd.

Ivor Jenkins was born in 1913 at Gorseinon, Swansea, and educated at Gowerton County School. From 1931 to 1934 he was Folland Scholar in Metallurgy at University College, Swansea, where he obtained a First Class Honours B.Sc. degree. He entered the G.E.C. Research Laboratories in 1934 as an 1851 Bursar, and the following year joined the scientific staff, where he was engaged on general metallurgical work, and in particular research studies on gas–metal systems relating to the heat-treatment of metals in controlled atmospheres. He was awarded the degree of M.Sc. in 1938 for a thesis on bright-annealing of low-carbon steel in controlled atmospheres.

From 1944 to 1945 he was Deputy Chief Metallurgist with the Whitehead Iron and Steel Co., Ltd., but he returned to the G.E.C. Research Laboratories in 1945; the following year he became Head of the Metallurgy Department. Dr. Jenkins (he was awarded the degree of D.Sc. by the University of Wales in 1948) was appointed to his present post in 1952. He is a Vice-President of The Institute of Metals and The Institution of Metallurgists and Chairman of the Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals. He was awarded the Williams Prize of The Iron and Steel Institute in 1946 for a paper on the coil-strip annealing plant of the Whitehead Iron and Steel Co., Ltd.

J. W. Stevens—Instruments Section, Physics Department, British Iron and Steel Research Association.

From 1940 to 1943, John William Stevens served with a fighter aircraft servicing unit; he was also engaged on the re-equipment of bomber aircraft for training purposes. He later joined the British Overseas Airways Corporation, where he worked in the aircraft electrical engineering department and in the communications and radar engineering test sections. Mr. Stevens joined B.I.S.R.A. in 1948; he has been engaged since then in the design and development of instruments for use in the steel industry.

J. W. Stevens

G. H. H. Williams

G. H. H. Williams, B.SC., PH.D—Section Head, Technical and Development Section, I.C.I. Ltd., Waunarlwydd Titanium Plant.

George Henry Houghton Williams was born in 1925 and educated at Gowerton Boys' Grammar School and University College, Swansea, where he was awarded a Folland Metallurgy Scholarship in 1943. After graduating in 1945, he spent two years in industrial research and development work before returning to University College in 1947, to investigate the strain hardening of metals during hardness testing; for this research work, carried out under the direction of Professor Hugh O'Neill, he was awarded the degree of Ph.D. in 1950. Dr. Williams then spent two years with Enfield Rolling Mills Ltd., before joining South Wales Aluminium Co., Ltd.; he was appointed Chief Metallurgist of the latter firm in 1954. He joined I.C.I. Metals Division in 1957.

AFFILIATED LOCAL SOCIETIES

Newport and District Metallurgical Society

The next session will mark the 25th anniversary of the foundation of the Newport and District Metallurgical Society. In recognition of this silver jubilee, a dinner is to be held on Friday, 24th October, at the King's Head Hotel, Newport, Monmouthshire.

EDUCATION

Summer School on Corrosion

The Department of Metallurgy of Battersea College of Technology, in conjunction with the Corrosion Group of the Society of Chemical Industry, is holding its fifth Summer School on Corrosion from 14th to 18th July. The theme of the school will be "Underground Corrosion and Cathodic Protection." The course is intended primarily to advance the knowledge of chemists, metallurgists, and engineers concerned with the corrosion and protection of underground pipes.

The Summer School consists of a series of lectures, demonstrations, and visits. The fee of £12 covers lunch and other refreshments. Applications should be made to the Secretary (Summer School), Battersea College of Technology, Battersea Park Road, London S.W.11, before 1st July.

Radioisotopes

An introductory course on radioisotopes is being held at the North Herts Technical College, Letchworth, from 14th to 16th May. The course is planned to answer many of the questions which present themselves to potential users of radioisotopes in their many applications. The fee for the course is £3 3*s*. 0*d*.; full details may be obtained from the College, Broadway, Letchworth, Herts.

M.I.T. Summer Programmes

A two-week special summer programme on "Metallurgical Applications of X-ray Diffraction" is being held at the Massachusetts Institute of Technology, Cambridge, Mass., U.S.A. from 18th to 29th August. The course will survey recent methods and techniques based on diffraction of X-rays by crystals for studying the problems of physical metallurgy. Those interested should contact Professor John T. Norton (Department of Metallurgy).

Other summer programmes at M.I.T. are devoted to "The Behaviour of Metals and Design Requirements for Elevated Temperatures" (17th–27th June) and "Metal Cutting" (17th–27th June). Further information may be obtained from Professor Nicholas J. Grant (Department of Metallurgy) and Professor Milton C. Shaw (Mechanical Engineering Department), respectively.

Careers Booklets from United Steel

The United Steels Companies Ltd. have recently issued three excellent booklets setting out the opportunities offered in the organization. They cover "Training for Student Apprentices," "Careers for Graduates," and "Careers in Research and Development." Each gives a general survey of the iron and steel industry and of the company itself and then sets out the current position with regard to recruitment, giving full details of selection procedure, training, opportunities, salaries, etc. Copies may be obtained from the Company Recruitment Officer, 17 Westbourne Road, Sheffield 10.

INSTITUTE OF METALS

Golden Jubilee Banquet

The Golden Jubilee Banquet of The Institute of Metals will be held, under the Presidency of Marshal of the Royal Air Force the Lord Tedder, in the Great Room of Grosvenor House, Park Lane, London, W.1, on Thursday, **1st May.** The Principal Guest will be The Right Hon. The Lord Hailsham, Lord President of the Council, who will be accompanied by Lady Hailsham.

NEWS OF SCIENCE AND INDUSTRY

Institute of Patentees and Inventors

Whilst industries having their own research organizations are fairly well supplied with new ideas, many manufacturers who are faced with difficulties beyond their resources to solve might be receptive to suggestions for new products and processes. The Institute of Patentees and Inventors is a non-profitmaking organization whose purpose is to act as an intermediary between industry and inventors, and to provide them with a common meeting place. Further details of the Institute's services may be obtained from the General Secretary, 207–208 Abbey House, 2–8 Victoria Street, London, S.W.1.

New Mill at Appleby-Frodingham

The Davy and United Engineering Co., Ltd., have built in their Darnall works at Sheffield a new four-high hot plate finishing mill for the Appleby-Frodingham Steel Company. The two roll housings, each of which weighs over 150 tons, are said to be the largest yet used in a British-built mill.

Mechanical Handling Exhibition

The 1958 Mechanical Handling Exhibition is being held at Earls Court, London, from 7th to 17th May. It is being organized by *Mechanical Handling*, one of the Iliffe group of trade and technical journals. The exhibition will cover an area of half a million square feet, and there will be over 300 stands representing all the leading British manufacturers, as well as international exhibits from France, Germany, Italy, Scandinavia, and the U.S.A. The Materials Handling Convention will be held at the same time, when papers dealing with the latest handling developments in many industries will be presented and discussed.

New R.T.B. Plant

Richard Thomas and Baldwins Ltd. are setting up a new press and fabricating plant at Gorseinon, near Swansea. Installation will be starting soon, and the new plant, which will be operated in conjunction with the present Cwmfelin works, is expected to be in full operation within a year.

Institute of Welding Spring Meeting

The Spring Meeting of the Institute of Welding is being held at Harrogate from 8th to 10th May. A full programme of technical sessions and works visits has been arranged, and the meeting is being preceded by a golf tournament.

Lancashire Steel Changes

The Lancashire Steel Corporation has been converted into a holding company. Manufacture of iron and steel has been transferred to a new wholly owned subsidiary, Lancashire Steel Manufacturing Co., Ltd., with an issued capital of about £15 million.

Davy United Leaves Park Iron Works

The Sheffield activities of Davy and United Engineering Co., Ltd., have been concentrated at their Darnall Works, Sheffield 9, which has become the head office. The company has disposed of the Park Iron Works in Sheffield, which they have occupied continuously since 1851, 21 years after the original founding of the company, to the English Steel Corporation Ltd. Darnall Works was first established in 1921 and has been systematically developed ever since, culminating in the recent building of a new headquarters block housing all engineering and administrative departments.

Waverley Essay Competition

The Waverley Gold Medal and a prize of £100 await the winner of this year's competition, sponsored by the journal *Research*. The competition is open to those engaged in scientific work, who are invited to write an essay of about 3000 words based on some recent scientific research or new development, giving some indication of the scientific background, the experimental results, and the potential industrial applications. Full details may be obtained from the Editor, *Research*, 4/5 Bell Yard, London, W.C.2.

Chemical and Petroleum Engineering Exhibition

The first Chemical and Petroleum Engineering Exhibition, sponsored by the British Chemical Plant Manufacturers Association and the Council of British Manufacturers of Petroleum Equipment, is being held at Olympia, London, from 18th to 28th June. During the Exhibition the Institution of Chemical Engineers and the Institute of Petroleum are holding a symposium on "The Organization of Chemical Engineering Projects."

Electric Fusion-Welded Pipe

At the Coatbridge works of Stewarts and Lloyds Ltd., equipment which has recently been installed for the manufacture of electric fusion-welded pipe comprises a continuous edge-forming and seam-welding machine for external welding and an internal welding boom for backing up welds. In comparison with a conventional fusion-welded pipe mill, fewer operators are required to

operate the equipment and the amount of time taken to change from one pipe size to another is reduced. Tacking of pipes before welding is not necessary and the use of multipower Unionmelt gives welding speeds which are twice those provided with single-wire welding. The Quasi-Arc/Torrance continuous edge former and seam welder forms the edges of the pipe and welds seams in one operation. It handles pipe from 18 in. to 50 in. o.d. in plate thicknesses up to $\frac{1}{2}$ in.

N.I.F.E.S. Summer School

"The Clean Air Act and Atmospheric Pollution arising from Combustion Processes" is the theme of this year's summer school, organized jointly by the North Wales Fuel Efficiency Panel of the Welsh Joint Education Committee and the National Fuel Efficiency Service. It is being held at the Prestatyn Holiday Camp from 9th to 14th June. The fee for the course is £10 for residential students (£4 for day students). Further details may be obtained from Mr. C. K. R. Davies, N.I.F.E.S., Baltic House, Mountstuart Square, Cardiff.

International Galvanizing Conference

Belgium will be the host country of the 5th International Galvanizing Conference this year from 22nd to 27th June. It will be held under the auspices of the Brussels Universal Exhibition; sessions will take place at Scheveningen and Knokke-le-Zoute. Details may be obtained from the Zinc Development Association, 34 Berkeley Square, London, W.1.

Production Exhibition

This year's Production Exhibition is being held at Olympia, London, from 12th to 21st May. The exhibition, which is to be opened by the Minister of Power, is divided into six main sections—production control, production in metals, services and aids to production, research and development, automatic production, and training and careers. The conference of the Institution of Production Engineers is being held concurrently with the exhibition.

Coal Preparation Congress

The 3rd International Coal Preparation Congress will be held in Belgium from 23rd to 28th June. Technical sessions will take place in Liège, and visits are being arranged to coalfields in Belgium and neighbouring countries. Details may be obtained from the Institut National de l'Industrie Charbonnière, 7 boulevard Frère-Orban, Liège, Belgium.

Australian Institute of Metals

The 11th Annual Meeting and Conference of the Australian Institute of Metals will take place in Melbourne from 26th to 30th May. A full programme of technical sessions and works visits has been arranged.

Tin Research Institute

A full year's work in pursuing new ideas and developing fresh applications of tin is described in the Annual Report of the Tin Research Institute, which appeared recently. The Institute's method of bonding aluminium–tin bearing alloys to steel has reached the commercial stage of development, and thousands of cars have already been fitted with the new bearings. Recent work sponsored by the Institute at the Battelle Memorial Institute is reported which shows that small amounts of tin may bring about desirable structural changes in cast iron without detriment to the mechanical properties. Copies of the report may be obtained from the Institute, Fraser Road, Perivale, Greenford, Middlesex.

London Drawing Office for United Steel

The United Steel Companies Ltd. are setting up a Central Drawing Office at 125–127 Victoria Street, London S.W.1, to provide facilities for design work on development projects and for detailed drawings of plant and engineering work required by the Company's branches. The manager of the new drawing office is Mr. R. M. W. Lowe, until recently with the Appleby-Frodingham engineering department.

Pneumatic Steelmaking Plants

The advent of the tonnage oxygen plant is bringing about a revolution in methods of steelmaking. Head Wrightson and Co., Ltd., have allied themselves to the German firm of Pintsch-BAMAG, and can now supply the three main types of pneumatic steelmaking plants to BAMAG designs: Kaldo, Linz-Donawitz, and Oxy-Thomas. At the same time careful economic assessments, relevant to the British scene, have been made of the various processes and different plant layouts.

Induction Furnace for High-speed Steels

A mains-frequency coreless induction furnace producing high-speed steels went into service recently in Sheffield. The furnace was built and installed by Birlec Ltd. in the works of the Inca Steel Company Ltd. The makers claim that this is the first time that such a furnace has been used to melt high-speed steels, and that the steel poured from this furnace is as clean as any made by established methods.

Non-destructive Testing

A three-day joint meeting of the Société Française de Métallurgie and the Institute of Physics on non-destructive testing is being held in Paris from 18th to 20th June. Papers from British and French authors are to be presented and discussed. Full details may be obtained from the Société, 25 rue de Clichy, Paris 9e.

British Conference on Automation and Computation

The Institution of Chemical Engineers, the Society of Instrument Technology, and the British Computer Society are organizing a symposium on "Instrumentation and Computation in Process Development and Plant Design," to be held on 11th to 13th May, 1959, at Central Hall, Westminster. Details of the symposium, which is under the aegis of the British Conference on Automation and Computation, may be obtained from the General Secretary of the Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

The Iron and Steel Institute is a member of Group A of the Conference—The British Group for the Engineering Applications of Automation—which was formally constituted on 20th February. The Group's objects are to foster the development of the engineering applications of automation, to form a common meeting ground for the member organizations, to maintain liaison with other groups of the Conference, to coordinate the presentation of British papers at international meetings, and to maintain contact with similar bodies in other countries.

Group B of the Conference—the British Group for Computation and Automatic Control—has accepted an invitation to cooperate in the 31st International Congress of Industrial Chemistry, to be held in Liège from 7th to 20th September.

Change of Address

The Institute of Marine Engineers has moved to the Memorial Building, 76 Mark Lane, London, E.C.3 (ROYal 8493).

Corrigendum

In the paper by Hultgren *et al.* (*J.I.S.I.*, 1958, vol. 188, March, pp. 247–261), the two lines at the foot of the right-hand column on p. 258 should be transposed to the foot of the right-hand column on p. 259 (after " easily ").

DIARY

28th Apr.–2nd May—Institute of Metals—Golden Jubilee Meeting—Church House, Westminster, London, S.W.1.

1st May—British Nuclear Energy Conference—Symposium on " Plutonium and Methods of Handling It "—Church House, Great Smith Street, London, S.W.1., 2.30 p.m.

1st May—Institute of Metal Finishing (North West Centre)—Annual General Meeting and Platers' Forum—Engineers' Club, Albert Square, Manchester, 7.30 p.m.

1st May—Institute of Metals—Jubilee Banquet—Grosvenor House, Park Lane, London, W.1.

1st May—Leeds Metallurgical Society—" Chromising," by Dr. M. L. Becker (preceded by Annual General Meeting)—Chemistry Wing, The University, Leeds, 7.30 p.m.

5th–8th May—National Welding Supply Association—Annual Meeting—Miami Beach, Fla., U.S.A.

7th May—The Iron and Steel Institute—Dinner for Members—Grosvenor House, Park Lane, London, W.1., 7 for 7.30 p.m.

7th–8th May—The Iron and Steel Institute—89th Annual General Meeting—London.

7th–17th May—Mechanical Handling Exhibition—Earls Court, London.

8th–10th May—Institute of Welding—Spring Meeting—Harrogate.

10th May—Swansea and District Metallurgical Society—Annual General Meeting—Central Library, Swansea, 6.30 p.m.

12th–17th May—Industrial Welfare and Safety Equipment Exhibition—Olympia, London.

12th–21st May—Production Exhibition—Olympia, London.

16th May—West of Scotland Iron and Steel Institute—All-day Conference on " Metallurgical and Engineering Aspects of Weight Saving in Steel Structures "—39 Elmbank Crescent, Glasgow.

26th–30th May—Australian Institute of Metals—11th Annual Meeting and Conference—Melbourne.

CO-OPERATIVE TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 392 of the April, 1958, issue of the Journal:

579. Markov: " Determination of Minimum Consumption of Electric Power in Arc Furnaces." *Stal*, 1957, May, pp. 419–422. (£3)

589. Fackert: " Structure of Scale on Hot Rolled Strips and Sheets." *Stahl u. Eisen*, 1955, Dec. 15th, pp. 1705–1710. (£3 10*s*. 0*d*.)

596. Saillard: " Investigations of Reinforcing Steels with an Elastic Limit of 60 kg/mm². Determination of a ' Tor-60 ' Steel." *Travaux*, 1954, Sept., pp. 437–451. (£5 10*s*. 0*d*.)

597. Ruehl: " American Tests on Brittle Fracture and the Resulting Conclusions on Testing of Brittle Fracture." *Arch. Eisenhüttenwesen*, 1954, Sept.-Oct., pp. 421–433. (£10)

605. Steiger: " Flame Heat-treatment of Rails for Points and Crossings and for Rail Ends." *Der Peddinghaus Erfahrungsaustausch*, 1955, No. 3, pp. 22–26. (£3 10*s*. 0*d*.)

606. Zingg and Geiger: " Metallurgical and Metalworking Problems of 12–15% Cr Steel." *Schweizer Archiv*, 1957, Apr., pp. 121–127. (£4)

611. Heil: " Works Experience of Waste-heat Boilers and Evaporative Cooling Installations for O.H. Furnaces, and Damage Sustained." *Stahl u. Eisen*, 1957, Jan. 24th, pp. 84–91. (£6)

612. Jacobi: " Methods of Cleaning the Waste-heat Boilers of an O.H. Furnace." *Stahl u. Eisen*, 1957, Jan. 24th, pp. 91–95. (£3 10*s*. 0*d*.)

628. TsNIITMash (Central Scientific Research Institute of Technology and Engineering): " Testing and Properties of Heat-resisting Materials." Mashgiz, Moscow, 1957 (vol. 79 of series). (Summary). (£3)

664. Decker: " The Desulphurization of Basic Bessemer Steel." *Rev. Univ. Mines*, 1957, May, pp. 165–212. (£10 text only; £1 for the 38 illustrations)

665. Weilandt *et al.*: " Dust Removal in a Strand Sintering Plant." *Stahl u. Eisen*, 1957, Aug. 8th, pp. 1064–1069. (£3)

666. Kopineck and Hoff: " Ultrasonic Testing of Sheets." *Stahl u. Eisen*, 1957, May 30th, pp. 727–734. (£4)

763. Flössner and Matthaes: " The Notched-bar Tensile Test and its Application for the Establishment of Tendency to Brittle Fracture." *Schweizer Archiv*, 1957, No. 8, pp. 249–258; No. 9, pp. 292–304. (£9)

767. Müller and Marx: " Results of Testing the Operation of Blooming Mills. Part I—Methods used in Measuring the Characteristic Data in Rolling Blooms." *Stahl u. Eisen*, 1957, Oct. 31st, pp. 1577–1582. (£3)

780. Novikov: " Effect of Surface Hardening by Heating with Mains Frequency Currents on the Properties of the Working Rolls for Cold Rolling." *Metallovedenie i Obrabotka Metallov*, 1956, June, pp. 36–47. (£5 10*s*. 0*d*.)

799. Schütte *et al.*: " Organisation of Supplies and Production, and its Place in Planning and Management." *Stahl u. Eisen*, 1957, Aug. 22nd, pp. 1146–1160. (£9)

803. Eckhard and Koch: " Spectrographic Determination of Trace Elements in Steel with Moving Electrodes." *Arch. Eisenhüttenwesen*, 1957, Nov., pp. 731–738. (£5 10*s*. 0*d*.)

808. Benes: " The Influence of Arsenic on the Properties of Steel." *Hutnické Listy*, 1957, No. 1, pp. 85–96. (£8)

814. Wiesner: " Rotary Piercing." *Hutnické Listy*, 1955, No. 3, pp. 130–139. (£5 5*s*. 0*d*.)

826. Schwarzmaier: " Continuous Casting of Tubes." Extracts from " Stranggiessen-Entwicklung u. Anwendung," Berliner Union G.m.b.H., Stuttgart, 1957, pp. 146–161. (£6 5*s*. 0*d*.)

829. Vach: " Rolling of Railway Tyres." *Hutnik*, 1957, No. 2, pp. 47–50. (£2 10*s*. 0*d*.)

831. Friedrich: " Effect of Steelmaking Procedure on Billet Quality and Seamless Tube Yields." *Hutnické Listy*, 1957, Dec., pp. 1077–1083. (£4 10*s*. 0*d*.)

835, 845–852: *Papers presented at the International Transport Conference held in London in September* 1957

835. Hubin: " Continuous and Semi-continuous Transport at the Cockerill-Ougree Works, Belgium." (£6)

845. Hoefl and Storcks: " Training and Education of Personnel for Rail and Mobile Transport in German Steelworks." (£3)

846. Brandani: " Transport by Conveyor Belt in an Iron and Steel Works." (£3 15*s*. 0*d*.)

847. Willem: " The Introduction of Radio in the Field of Transport—the Position in Belgium." (£3 10*s*. 0*d*.)

848. Paris *et al.*: " Belt Conveyors in the Iron and Steel Industry." (£8 10*s*. 0*d*.)

849. Vierling: " Transport by Conveyor Belts in Iron and Steel Works." (£6 5*s*. 0*d*.)

850. Maury: " Use of V.H.F. Radio in the Internal Transport of Steelworks." (£5 10*s*. 0*d*.)

851. Forterre: " Recruitment and Training of Internal Transport and Handling Personnel at the Thionville Works." (£2 5*s*. 0*d*.)

852. Saul and Bergrath: " Signal Installations and Communication Techniques used in the Transport of Materials in a Steelworks." (£5 10*s*. 0*d*.)

836. Ferry and Roques: " Soundness of Large Forging Ingots." *Rev. Mét.*, 1957, March, pp. 175–180. (£3)

853. Klärding: " Selection of Tool Steels for Hot Working." *Metall*, 1958, Jan., pp. 12–20. (£4 10*s*. 0*d*.)

854. Olette and Hanin: " A Note on the Determination of Oxygen in Steels." *Berg- u. Hüttenmännische Monatsh.*, 1953, No. 7/8, pp. 238–244. (£3 10*s*. 0*d*.)

855. Feichtinger: " A Further Development in Vacuum Hot Extraction Analysis." *Berg.- u. Hüttenmännische Monatsh.*, 1953, No. 7/8, pp. 230–238. (£5)

857. Popov: " The Technological Requirements for Automation of Wire and Wire Products Production." *Stal*, 1957, Dec., pp. 1128–1130. (£2)

861. Gebling and Zimmer: " Use of Oxygen in an Open-hearth Steelworks." *Stahl u. Eisen*, 1958, Feb. 6th, pp. 156–160. (£3)

865. Reckmann and Misch: " Smelting Trials with Swedish Ore Pellets." *Stahl u. Eisen*, 1958, Jan. 9th, p. 21. (£4)

871. Strauss and Roth: " Fundamentals of Acid Copper Plating and of the Cupatier Process." *Metalloberfläche*, 1957, Sept., pp. 281–285. (£3 10*s*. 0*d*.)

882. Ferro and Montalenti: " Variations in the Magnetic and Mechanical Properties of Iron, caused by Hydrogen Solution." *Il Nuovo Cimento*, 1957, Apr. 1st, pp. 842–852. (£3)

883. Brodetsky and Pikalov: " Automatic Regulation of Hot Blast Stove Heating." *Stal*, 1958, Jan., pp. 21–22. (£1 10*s*. 0*d*.)

889. Severing: " Design and Performance of a Modern Continuous Medium Strip Mill." *Stahl u. Eisen*, 1958, Feb. 20th, pp. 205–214. (£6)

892. Antoni: " Accidents in the German Iron and Steel Industry, 1956—Works Accidents Statistics." (Abridged). *Stahl u. Eisen*, 1957, Nov. 14th, pp. 1692–1698. (£2)

893. Köhler: " The Hydrocyclone as Part of the Water Circulation System in an Integrated Steelworks." (Abridged). *Stahl u. Eisen*, 1958, Feb. 20th, pp. 235–239. (£2)

900. Koch *et al.*: " The Formation of a Cubic Nitride in Aluminium-containing Steels." *Arch. Eisenhüttenwesen*, 1956, Nov., pp. 701–706. (£3 10*s*. 0*d*.)

907. Guessier and Castro: " Simple Machines for the High-temperature Testing of Steels and Alloys." *Rev. Mét.*, 1957, No. 2, pp. 101–106. (£3 15*s*. 0*d*.)

908. Dahl and Lueg: " Drawing and Push-pointing of Cold-rolled Steel Bars." *Stahl u. Eisen*, 1957, Dec. 12th, pp. 1795–1802. (£5)

910. Neff: " A New Counter Goniometer for Determining the Texture of Sheet Materials." *Z. Metallkunde*, 1956, Sept., pp. 646–649. (£2 5*s*. 0*d*.)

926. Kalinnikov and Samarin: " Effect of Refractory Materials of Steel Pouring Devices on the Content of Non-metallic Inclusions in Steel." Conf. Acad. Sci. U.S.S.R. on Peaceful Uses of Atomic Energy, Sec. Div. Tech. Sci., 1955, pp. 3–27. (£4 10*s*. 0*d*.)

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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Abstracts in which the reference is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

The Iron Ore of the Cia. Vale do Rio Doce. (*Eng. Min. e Met.*, 1957, **25**, May, 266–267). [In Portuguese]. This company owns large mines in Itabiri, Brazil, and gives facts and figures about its developments to increase production and export. About 300 × 10^6 t of high grade ore are immediately exploitable. Last year, 2½ × 10^6 long tons were exported, 44·5% to the U.S.A. and 24·4% to Britain.

Chromium and Nickel-bearing Iron Ore Deposits in Yugoslavia. V. Simić. (*Rudarsko-Metalurški Zbornik*, 1957, (4), 361–367). [In Serbo-Croat]. An account is given of the geological and chemical characteristics of recently discovered rich deposits in Serbia.

The Chromite Deposits in the Raduša Region. I. Krivčenko. (*Rudarsko-Metalurški Zbornik*, 1955, (3), 173–179). [In Serbo-Croat]. An account is given of the geological character, location, and history of the rich chromite deposits in southern Yugoslavia. Production of chromium and ferrochrome is to be expanded to cover domestic demand and provide an exportable surplus.—P. F.

Genetic Types of Chrome-Ore Deposits and their Location. W. E. Petrascheck jun. (*Z. Erz. u. Metall.*, 1957, **10**, June, 264–272). The location of chrome-ore deposits is discussed in relation to geological conditions and petrology. Various methods of location are discussed but none of these is considered to be perfectly efficient. (24 references).—R. P.

Geochemistry and Problems of Genesis of Kerch Iron Ores. V. F. Malakhovsky. (*Problems of Mineralogy of Sedimentary Formations, Lvov Univ. Publ.*, 1956, **3–4**, 190–202). Geochemical mapping of Kerch ores helps to explain the distribution and relations between the various chemical elements present and to elucidate the geological history of the ores.

Mineralogy of Biomorphoses as Related to the Genesis of Iron Ores of the Azov Region. A. U. Litvinenko. (*Problems of Mineralogy of Sedimentary Formations. Lvov Univ. Publ.*, 1956, **3–4**, 174–189). A study of the replacement of animal and plant remains by carbonates, phosphate and iron compounds as related to the problem of genesis of the Fe–Mn ores of the Kerch and Taman regions.—S. I. T.

Geochemistry of Anthigenous Siderites. M. S. Tochilin. (*Problems of Mineralogy of Sedimentary Formations. Lvov Univ. Publ.*, 1956, **3–4**, 203–211). A general survey of geochemistry and the genesis of siderite ores.

Iron and Manganese Ores of Singhbhum, Keonjhar, and Bonai. M. V. Wazalwar. (*Tisco*, 1957, **4**, Oct., 204–211). The author describes the nature of formation of the ores and details typical analyses. The various banded rocks and types of iron ores are introduced and illustrated by photographs. (12 references).—L. E. W.

The Operation of the Iron Ore Company of Canada. A. Choubersky. (*Bull. I.M.M.*, 1957, **67**, Nov., 33–88). A complete account is given of geology, mining, labour, railways, and shipping.

ORES—MINING AND TREATMENT

Home Ore Development. (*Steel Rev.*, 1957, Oct., 11–19). An account of British iron ore resources and problems of exploitation is given.

Iron Ores from Overseas. E. F. Fitzhugh jun. (*Blast Furn.*, 1957, **45**, Oct., 1154–1155). A review of U.S. imports, mainly from South America.

Western Iron Ore Output Increases. (*Eng. Min. J.*, 1957, **158**, Oct., 82–83). Notes on various Western U.S. locations are given.

A Survey of Surface Workings of Yugoslav Iron Ore Deposits. K. Tarter. (*Rudarsko-Metalurški Zbornik*, 1956, (4), 369–394). [In Serbo-Croat]. A detailed description is given of methods used at the various open-cast mines. A comprehensive abstract in German is provided.—P. F.

Iron Ore Mining in Yugoslavia and in the World in General, With Special Reference to Underground Mining. A. Gogala. (*Rudarsko-Metalurški Zbornik*, 1956, (4), 305–325). [In Serbo-Croat]. A description is given of mining methods developed for use in exploiting the comparatively lean ores occurring in Yugoslavia.—P. F.

Iron Ores of the Chinese Peoples' Republic, the Degree to Which They Have Been Prospected, Their General Characteristics. I. P. Bardin. (*Izvest. Akad. Nauk, Otdel. Tekn.*, 1957, (8), 109–119). [In Russian]. This article, compiled from material from È. Yu-pei, describes the main Chinese iron-ore deposits, the properties of the ores and some of the methods used for their concentration.—S. K.

Whyalla. (*Iron Steel*, 1957, **30**, Oct., 472–474). An account is given of the Broken Hill Proprietary Co.'s developments at Whyalla. These concern the further extraction of ore from the ore mountains, and new construction in the shipyards.—G. F.

Survey of Development at Iron Monarch. (*B.H.P. Rev.*, 1957, **34**, Aug., 2–4). An illustrated account of ore mining at Whyalla, Australia.

The Measurement of Rock Pressure: A Method for Obtaining Absolute Stress Values. N. Hast. (*Jernkont. Ann.*, 1957, **141**, (10), 633–745, discussion, 745–752).

Transport of Iron Ores. J. Bernard-Michel. (**Stahl Eisen*, 1957, **25**, Nov. 28, 1729–1733). Various locations of crushing plant relative to the mines and furnaces are considered and the choice of means of transport and of the wagons to be preferred is discussed. Sinter plant and the transport of fines is also reviewed and notes on stocking and reclaiming by conveyor or crane are added.

Transportation and Handling of Iron Ore for Use in German Iron Works. A. Pöhner. (**Stahl u. Eisen*, 1957, **77**, Oct. 17, 1417–1426). The author reviews the transportation and handling of iron ore in Western Germany. The steadily increasing consumption will require additional transportation and handling capacities by 1960, as present capacity is fully employed. A number of handling plants should be replaced by more modern equipment.—T. G.

Annotated Bibliography of High-Calcium Limestone Deposits in the United States Including Alaska, to April 1956. G. C. Gazdik and K. M. Tagg. (*U.S. Geol. Survey Bull.*, 1019–I, 1957, 675–713).

Determination of Dehydration Temperatures by Means of Differential Thermal Analysis. B. Dobovišek. (*Rudarsko-Metalurški Zbornik*, 1956, (1), 25–31). [In Serbo-Croat]. The components of some Yugoslav iron ores were identified by the measurement of dehydration and decomposition temperatures.—P. F.

Determination of the Most Profitable Average Metal Content in Ores. W. Stepinski. (*Arch. Hutn.*, 1953, **1**, (3/4), 257–270). [In Polish]. Functions covering beneficiation and smelting are derived.

The Chemistry of Roasting Reactions in Copper and Iron Sulphides. K. Cazafura and

B. Dobovišek. (*Rudarsko-Metalurški Zbornik*, 1956, (3), 193–210). [In Serbo-Croat]. An account is given of a series of experiments designed to explain the character and sequence of roasting reactions. Differential thermal analysis was used.—P. F.

Caustic Leaching of Manganese Flotation Concentrate from Artillery Peak, Arizona. E. C. Perkins. (*U.S. Bur. Mines, Rept. Invest.*, 1957, No. 5341, June, pp. 16). Laboratory studies are reported.

Swedish Mineral Dressing Mills. E. Rothelius. (*International Mineral Dressing Congress, Stockholm*, 1957, pp. 211). A collection of short descriptions of plants in Sweden, classified by the type of ore treated and including ores of non-ferrous metals.

Control of Quality and Statistical Analysis of Data from Metal Flotation Plants. R. Duval. (*Ann. Mines*, 1957, Nov., 726–747).

Measurement of Aeration in Flotation Cells. W. Gründer, W. Siemes, and J. F. Kauffmann. (*Z. Erz. Met.*, 1956, **9**, Dec., 559–565). A method of measurement of bubble size is described and cell construction and flotation agents discussed.

On the Phase Boundary Potential and its Meaning in Adsorption, in Flotation Processes and in Chromatography. B. Kamiensky. **Electrical Phenomena of the Flotation Process.** A. Pomianowski. (*Proc. Electrochemical Conference* 1955, *Warsaw*, 1957, 5–70, 202–206; discussions, 207–218). [In Polish with Summaries in Russian and German].

Heat-Treating Iron Ore Concentrates. (*Min. J.*, 1957, **249**, Nov. 29, 650). The Allis-Chalmers process is described.

Installation for the Enrichment of Lapland Iron Ore. (*Eng. Min. e Met.*, 1957, **25**, Apr., 181–182). [In Portuguese]. A brief account of the plant at Kiruna is given, with details of its construction, capacity, and methods of disposal of the products.—P. S.

Furnace Makes Strong Ore Pellets. (*Steel*, 1957, **141**, Sept. 23, 128–130). A process developed by Allis-Chalmers Mfg. Co. for making strong taconite pellets is described. A pilot plant is being studied with a view to full scale development. The operation has 4 steps:—1, forming pellets; 2, drying pellets on a moving grate; 3, heating (partially oxidising) pellets on a moving grate; 4, burning pellets in a short rotary kiln. Fuel consumption is low as waste gases from one part of the process are used in the previous ones. Dust and fines are retained in the system.—D. L. C. P.

Process Cuts Pelletising Costs. (*Eng. Min. J.*, 1957, **158**, Oct., 75–77). The Allis-Chalmers process is described for magnetite concentrate for blast furnace use. Plans and diagrams are given and heat treatment and the reactions involved are outlined.

The Production of Burden Briquettes Made from Ore, Brown Coal and Basic Fluxes Without the Use of Binders. W. Petersen and S. Wawroschek. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1427–1435). Fine ore was mixed with soft lignite and slaked lime and compacted at pressures between 500 and 3000 kg/cm². The ore was rich in SiO_2 and rather low in iron. Ore and lignite should be as fine as possible, the grain-size was below 60 μ. Green strength, and crushing strength in the low-shaft furnace, were excellent, although the briquettes should not be stored for more than 48 hr. as their crushing strength in the furnace decreases after that period.—T. G.

Colloquium on the Sintering of Iron Ores. (*IRSID Publ., April* 1956, *Metz*, 1957, May, pp. 199). **The Development of Sintering. Choice of Sintering Process.** J. Astier. (7–25). The sintering of residues, of concentrates and of ore fines are reviewed. Appendices give data on U.S. developments, U.S.S.R. developments, British developments, plants in France, Belgium, Luxembourg and the Sarre using minette ores and on the desulphurisation of ores. **Trends in the Construction of Modern Plants with Continuous Bands. (Dwight-Lloyd System).** J. Astier. (27–38). Charge preparation, the moving hearth, screening and cooling, control and operation of the plants are outlined with rough diagrams. **The Mechanism of Sintering on Grids. Method of Investigation by IRSID and the Programme.** J. Michard. (39–52). The laws of gaseous flow through the bed are given, the process of carbon combustion is reviewed and the thermal balance drawn up. **Granulometric Properties of Sinter from Knutange.** M. Pasquet. (53–68). Comparison with U.S. sinter and application of the data to the control of production are also briefly considered. **The Problem of Supply of Fuel Presented by the Development of Sintering.** P. Massin. (69–76). Coke dust requirements and estimates of supplies are considered. **Sintering in the Revolving Furnace.** J. Paquet. (77–81). Practice in the ARBED works in Luxembourg is outlined with chemical and physical data. **Greenawalt Sintering by the Soc. Blast Furnaces de la Chiers.** M. Rondet. (83–88). An outline of the plant with some dimensions, data on charges and analyses of charge and sinter, and a discussion of advantages and disadvantages. **Sintering of Ore at the Usine de Micheville.** M. Dumousseaux. (89–100). The plant is described and illustrated, the advantages and disadvantages are outlined and analyses are given and an account of charge preparation. **Replacement of Part of the Solid Fuel by Blast Furnace Gas on the Dwight-Lloyd Conveyor. Thermal Balance of the Sinter Plant at Burbach.** E. Daubenfeld. (101–118). The plant is outlined and much data on operation is given, materials and thermal balances are elaborated. **Dwight-Lloyd Sintering by the Soc. Mét. de Knutange.** P. Thierry. (119–124). A brief account of the installation and the dust collecting system. **Use of Sinter in the Blast Furnace.** M. Brun and F. Douez. (125–137). Considerable operational data are tabulated for coke consumption and gas composition, with thermal balances and graphical data on production and temperatures. **Effect of Use of Sinter on the Operation of Blast Furnaces of the S.M.K. [Knutange].** M. Brun. (139–144). Modifications of furnace profile are shown. **Adaptation of the Blast Furnace to the Use of Sinter.** A. Heczko. (145–163). A discussion of smelting conditions and of furnace volume required is given with tabulated operational data and many furnace sections. **Economic Value of Charge Preparation. Crushing of Ores and Sintering of Fines.** G. Aubert. (165–176). The costs of crushing and sintering are considered and related to pig-iron production. **Estimation of the Cost of Production in Plants Designed for Large Outputs.** J. Astier. (Note added later, pp. 3). Dwight-Lloyd plant is considered and estimates of costs tabulated. **The Operation of Blast Furnaces with Large Proportions of Sinter.** J. Astier. (177–199). A review of furnace design and production with appendices on Russian and other designs and on coke consumption.

The Chemistry and Physics of the Sintering of Iron Ores. A. Roos. (*Génie Civil*, 1957, **134**, March 15, 129–133). A review of the methods and of the chemistry of the processes involved.

Material Handling in the Sinter Process. M. V. Laan. (*Blast Furn. Steel Plant*, 1957, **45**, July, 727–730). A short review of raw material and sinter handling in sinter plants and the conditions of service of the equipment is presented.—B. G. B.

A Charging Device for Experimental Sinter Plants. A. G. Neyasov. (*Stal'*, 1957, (10), 883). A device securing more uniform distribution of the burden with regard to lump size is described which improves reproducibility of the experiments.

Review of Developments in the Sintering Process. M. F. Morgan. (*Blast Furn.*, 1957, **45**, Oct., 1142–1144). A brief review is given in 10-year sections from 1920 to 1959.

Thoughts on Sintering in Great Britain. R. F. Jennings. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 7, 1459–1464). The increased use of sinter in Great Britain is discussed and the benefits derived by using high sinter burdens, in particular at Appleby Frodingham, are explained. The economic justification for increased use of sinter is reviewed.—B. G. B.

Intensification of the Process of Sintering Iron Ores. A. E. Lebedev. (*Metallurg*, 1957, (5), 10). Tests under laboratory conditions on the sintering of Kerchensk ores showed that as the carbon content of the sinter burden increased, gas penetration and the vertical speed of sintering were lowered. A new method of making the sinter mix in which ore is first added to the mixing drum without the coke fines, and mixed and moistened for five min, when the requisite amount of coke fines is added and mixed in for three min, is described. More rapid sintering and better sinter are obtained by this method.—B. S.

Intensification of the Sintering Process by the Burning of Limestone on the Sinter Charge Bed. D. A. Kissin and A. V. Drimbo. (*Stal'*, 1957, (10), 868–873). The Zaporozhstal plant has developed a method for burning limestone for the sinter charge on the sinter plant itself. Optimum conditions are: humidity of charge 6–7%, coke breeze content, 10%, lump size of limestone 0–3 mm and quantity of mixture 2 kg per 0·1 m² of surface area. The process is intensified by 10·5% for unslaked and 8·0% for slaked product. The product is removed from the sinter layer and transferred to the charge by the returned fines unit or through the defuming plant.—B. S.

FUEL—PREPARATION, PROPERTIES, AND USES

Steel and Power. (*Steel Rev.*, 1956, Apr., 1–6). Statistics on fuel consumption are indicated graphically and related to output.

On the Assessment of Coal Quality on the Basis of the Dilatometric Contraction. V. Kúdela. (*Paliva*, 1957, **37**, (8), 269–271). [In Czech]. In number 6 of *Paliva* the author showed that the dilatometric contraction of coals not exhibiting dilatation may be taken as a measure of the transition of the coal into the plastic state. In the present work theoretical and experimental work is advanced to show the close connection between such a dilatometric contraction and the amount of the liquified volume fraction in the coal. This fraction is determined by petrographic factors and is thus an index of quality.—P. F.

Recovery of Fines in the Preparation of Coal by the Wet Method. K. Slokan, I. Kocmur, and D. Ocepek. (*Rudarsko-Metalurški Zbornik*, 1957, (2), 111–123). [In Serbo-Croat]. Experiments carried out so far showed that a very satisfactory recovery of fines from water is possible by the use of cyclones fed with the coal-bearing liquid. Operating schedules are given. Experiments to determine conditions for optimum performance are still in progress.

Coal Preparation and Coal Washing Plant at the Danube Iron Works. J. Schwertner and I. Schumicky. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 359–364).

Fuel Problems of the Jesenice Ironworks. M. Marolt. (*Nova Proizvodnja*, 1954, **5**, (3–4), 207–215). The coal available, the possibility of lignite gasification and gas enrichment, and the use of electric power as a fuel replacement are discussed.

Laboratory Study of Coal Blends. M. Boyer. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 7, 1429–1431). A short report on the influence of particle size and relative proportions of two coals on the bonding temperature of the mixture is presented.—B. G. B.

Production and Preparation of Coking Coal from Komlo [For the Danube Steelworks]. G. Boday. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 348–358).

A Short Description of the Coke-Oven Plant of the Danube Iron Works. G. Pesti. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 364–371).

The Kinetics of Coal Carbonization. D. Fitzgerald. (*Inst. Gas Eng. Comm.*, No. 516, 1957, Nov., pp. 42).

Heating Up Ravenscraig Coke Oven Battery with Oil and Propane. (*Gas World*, 1957, **146**, Dec. 7, Coking, 124–128).

Fuel for Expansion. (*Steel Rev.*, 1956, Apr., 23–40). **Coal.** E. F. Schumacher. (26–30). **Oil.** C. Dalton. (31–34). **Electricity and Atomic Power.** E. Shankleman. (35–40). Coal, oil, and electricity supplies and demands of the steel industry are shown graphically and future outlook discussed.

One Year's Working with 100% Sarre Coal at the Dilling Coke Oven Plant. P. Desfossez. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957,

No. 7, 1433–1439). A description is given of the practice of this plant which treats part of the raw coal in a Krupp–Lurgi semi-coke plant and incorporates a certain proportion of this product in the coke-oven feed. The results obtained are described and have been very satisfactory.—B. G. B.

Production and Preparation of By-Products of the Coke-Ovens and Description of the Chemical Plant at the Danube Iron Works. E. Tomaschek and G. Dancshazy. (*Koh. Lapok*, 1957, **12**, Aug.-Sept., 371–377).

The Treatment of Coal Tar at the Marienau Works. P. Le Roux. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 7, 1451–1454). The treatment of coal tar from the high temperature and low temperature carbonization of coal is described.—B. G. B.

Closed Circuit Television in Coke-Oven and Steelworks Plant. L. Walter. (*Coke Gas*, 1957, **19**, Nov., 464–467, 474). Equipment and its uses are mentioned. Little is said about steel.

Chemicals from Steel Plants. (*Chem. Eng. News*, 1957, **35**, Aug. 26, 19–22). Possibilities of obtaining coke-oven by-products, ammonia, gases and oxygen are referred to.

Application of Differential Thermal Analysis for Testing Solid Fuels. B. Dobovišek. (*Rudarsko-Metalurški Zbornik*, 1956, (2), 107–124). [In Serbo-Croat]. Ignition temperatures, reactivity and other properties of solid fuels, such as electrode graphite, petroleum coke, Ruhr coke, charcoal and lignite, were determined by DTA. The results are shown to agree with those obtained by conventional methods.—P. F.

International Standardisation of the Measurement of the Physical Properties of Cokes. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 7, 1441–1450). A summary is given of the proceedings of international meetings held in London and Essen to discuss this subject.

Micro-strength Test of Cokes. N. N. Das Gupta, D. Mukherjee, and S. N. Sinha. (*J. Sci. Ind. Res.*, 1957, **16A**, Sept., 419–423). The N.C.R.C. method was used. The usual small scale laboratory tests are shown to be unsatisfactory.

Scientific Principles on which the Different Methods of Gasification of Solid Fuels Depend. H. Cassan. (*Chaleur et Ind.*, 1956, **37**, Nov., 301–317; Dec., 341–358; 1957, **38**, Jan., 7–16; Feb., 41–54; April, 95–112).

Heat Transfer by Radiation from Flames. R. A. Sherman. (*Trans. A.S.M.E.*, 1957, **79**, Nov., 1727–1741). A summary of the work of the International Flame Research Foundation. (With discussion).

The Origin and Elimination of Nitrogen Dioxide in Coke Oven Gas. B. Lefrançois. (*Chim. et Ind.*, 1957, **78**, Sept., 193–197).

The Use of Town Gas in Industry. (*Ind. Heat. Eng.*, 1957, **19**, Sept., 269–271). Various heat-treating installations are mentioned.

AIR POLLUTION AND SMOKE

Industry and the Clean Air Act. L. A. W. Jenkins. (*Iron Steel*, 1957, **30**, Oct. 9, 568–570). A discussion of the impact on industry of the new legal requirements with examples of special cases and economic aspects of dust collection and smoke prevention is given.

Damage from Smelting Smoke and Waste Gases. K. Guthmann. (*Stahl u. Eisen*, 1957, **77**, Nov. 28, 1762–1764). A review of published information on smoke, waste gases, and air pollution from metallurgical smelting and melting shops in the ferrous and non-ferrous metal industry. The health hazards of the individual industries are described, in some instances means of suppressing pollution are given.—T. G.

The Treatment of Gaseous Effluents. A. Aikens. (*Met. Fin. J.*, 1957, **3**, July, 281–283, 288). The Oxycat process for catalytic oxidation and heat recovery is described.

Electric Furnace Fumes Vacuum Cleaned to Prevent Air Pollution. (*Ind. Heat.*, 1957, **24**, Sept., 1750, 1752, 1754). The National Supply Co. installation at Torrance, Calif., is described, with 780 15-ft bags moving 75000 ft³/min of dust-laden air from ducts over the furnaces.

Dust Problems of the Iron and Steel Industry. M. W. Thring and R. J. Sarjant. (*Iron Steel*, 1957, **30**, Oct. 9, 571–573). The O.H., Bessemer and electric arc furnaces, the blast furnace and cupola and heat-treatment furnaces are briefly discussed.

Dust Control. (*Iron Steel*, 1957, **30**, Oct. 9, 536–541). A general account of particulate matter and methods for its removal is given. Types of precipitators and dedusters are described and a table of approximate costs is given.

Maintenance for Dust Control Systems. L. M. Johns. (*Foundry*, 1957, **85**, Oct., 124–127). Inspection and repair schedules are suggested.

Wetting Agents in Dust Control with Special Reference to the Wetting of Finely Distributed Iron Oxides in Foundry Smoke. R. Meldau. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 615–621). A general survey of the use of wetting agents in dust control is presented. The physics of wetting, the properties of wetting agents, the effect of particle shape on wettability, and the part played by iron oxide in this context are discussed. The feasibility of wetting brown smoke with a large variety of wetting agents is discussed in detail. Means of consolidating slurries and spoil heaps, and the use of a combination of several methods of operation to reclaim iron oxides in a pure form are briefly mentioned.—L. J. L.

TEMPERATURE MEASUREMENT AND CONTROL

Temperature Measurement. W. E. Belcher jun., D. Robertson, and W. F. Hickes. (*A.S.M. Publ.*, 1956, pp. 75). Thermocouple and radiation pyrometers and filled system and resistance thermometers are reviewed.

Progress in Industrial Temperature Measurement, Part I. H. Lindorf. (*Draht*, 1957, **8**, Sept., 395–398). In this article contact thermometry is surveyed, with information on the various types and their performance, and on methods of indication of temperature. **Part II.** (Oct., 435–437). This part is devoted to radiation pyrometers. Included are brief descriptions of the working principles and performance of lens and mirror total radiation pyrometers, and of partial radiation pyrometers, and sources of error are discussed.

Industry Looks at Thermal Image. (*Iron Age*, 1957, **180**, Oct. 17, 76). The principle and uses of the thermal image camera are described. Being sensitive to infra-red emissions, this type of thermal photography can be used below 1000° F; it can record temperature differences as small as 0·02° C. The method has great possibilities for measuring temperature distribution and detecting hot spots on industrial plant.—D. L. C. F.

Measurements of Surface Temperatures. M. Bartuška, J. Hlavač, and S. Procházka. (*Silikáty*, 1957, **1**, (1), 85–86). [In Czech]. In measuring the thermal conductivity of refractories on small samples by the sandwich method difficulties arise in measuring the temperatures of the surfaces of the sample. A new method was developed. This depends on measuring the thermal e.m.f. of a thermocouple consisting of the refractory and a metal, such as silver, which has been sintered into the former. The couple is calibrated by comparison with a standard Pt–PtRh thermocouple. The method was used successfully up to 700° C.—P. F.

Means of Determining Temperature Distribution by Means of Radiation-Sensitive Layers. R. Lenz. (*Electrowärme*, 1957, **15**, Nov., 383–387). A review of temperature-sensitive coatings and their uses, including infra-red, phosphorescent, evaporagraphic, and thermographic techniques.

Continuous Measurement of Temperature in the Tuyere Zone of Blast Furnaces. I. F. Koval' and A. Ya. Kravchenko. (*Metallurg*, 1957, (3), 6–8). The Kostogryzov system of continuous temperature measurement through the tuyeres is described. Even with a level rate of blast consumption and constant blast temperature, the temperature in the tuyere zone does not remain constant but depends on the gas permeability of the stock. The descent of a new portion of the charge at the throat causes a rise in temperature in the tuyere zone but, as the charge descends, the temperature in the tuyere zone is lowered. The variation in temperature is related to the time of descent of the stock. Other factors affecting it are high top pressure, the use of self-fluxing sinter and the moisture content of the blast.—B. S.

A Trend in Steel Plant Temperature Measurements. C. Maloney. (*Blast Furn.*, 1957, **45**, Oct., 1156–1158). A description of the Land surface pyrometer is given. A small thermopile is mounted with a long telescopic handle for putting in contact with the surface to be examined. It reads from 100°–2400° F.

Evaporograph Measures Interior Wall Temperatures. (*Blast Furn.*, 1957, **45**, Oct., 1140–1141). The use of the evaporograph for determining temperature distributions is described. It depends upon preferential condensation of oil on parts of the infra-red image at relatively lower temperatures and detects this by interference colour production. It is sensitive to ± 1° C and will operate up to 3 miles from the target.

Colour Eye Looks Inside Blast Furnace. (*Can. Metalw.*, 1957, **20**, Oct., 40). A note on the "evaporograph."

Experiences With Thermocouples Used for Bath Temperature Measurements in Open-Hearth Furnaces. S. Čop. (*Rudarsko-Metalurški Zbornik*, 1956, (1), 49–52). [In Serbo-Croat]. An immersion pyrometer utilizing a Pt–Pt/Rh thermocouple in a silica sheath was developed and utilized for studies of melting schedules at the Jesenice Steelworks. Sources of likely error in the measurements are discussed, and conclusions as to optimum bath temperatures etc. are listed.—P. F.

Measurement of Temperature of Liquid Steel with Immersion Pyrometers. M. M. Epshtein. (*Metallurg*, 1957, (2), 11–14). The immersion pyrometers used at the Kuznetsk plant and their application in O.H. and arc furnaces are described. Methods of repair are indicated.

On the Accuracy of Temperature Measurements on Molten Steels with Immersion Thermocouples of Various Types. A. N. Gordov and N. N. Ergardt. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 727–730). A criticism of the types of thermocouples generally in use is made on the ground of lack of accuracy in the measurements of temperatures. Pending the development of more suitable thermocouple metals, a change over to the type P.P.C. is suggested. This thermocouple contains an alloy with 10% Rh which is more stable and more reliable at temperatures above 1000°.—L. H.

A Contribution to Temperature Measurement in the Arch of Open-Hearth Furnaces by Thermoelectric Methods. H.-J. Kirschning, E. Hochstrate, and H. Rodrian. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 611–614). The performance of various protective sleeves of ceramic materials for thermocouples used in measuring arch temperatures has been studied. When the diameter of the sleeves is kept small, to prevent the formation of heat stress, the major problem consists in the penetration of the sleeve wall by carbon, which affects the structure of the materials examined in different ways. BeO was found to be the most suitable material for these sleeves.—L. J. L.

Calculating the Temperature in Tunnel Gas Burners. L. I. Druskii, V. M. Ivanov, and B. V. Kantorovich. (*Stal'*, 1957, (10), 951–957). Flameless combustion in fireclay tunnel burners is attained with an excess air not exceeding 1·1, it proceeds practically uniformly across the whole section when the walls are incandescent. Approximate calculations are made and theoretical curves constructed in good agreement with observations.—B. S.

REFRACTORY MATERIALS

Refractories in the Steel Industry. (*B.H.P. Rev.*, 1957, **34**, Aug., 5–7). A non-technical survey.

The Vital Role of Refractories in the Modern Manufacture of Steels. (*Ing. e Indust.*, 1957, **25**, July, 89–95). [In Spanish]. Service conditions and requirements of refractories in the iron and steel industry are discussed. Suitable refractory materials for each type of furnace are indicated.—P. S.

Production and Uses of Firebricks of Com-

plex Shapes Made by the Zirconal Process. H. Rohn. (*Elektrowärme*, 1957, **15**, Oct., 365–366). Ethyl silicate up to 4% is used as binder and the shapes can be slip-cast. The low bonding ratio and great homogeneity give good refractory properties.

Alumino-Silica Refractories of the Rio Grande do Sul. F. J. Gross. (*Anais Assoc. Brasil. Quim.*, 1954, **8**, June, 81–91). [In Portuguese]. Samples of bricks from four manufacturers in this region of Brazil have been studied. The raw material contained from 54 to 68% silica, and 23 to 40% alumina. Chamotte was added in every case, manufacture being by extrusion and press, natural drying, and firing at 1200–1400° C. A comprehensive range of tests were made; these are described briefly and the results are reported in tabular form. It is concluded that these refractories come within the Group III classification (Intermediate Heat Duty Fireclay Brick), but, with closer control of selection and production methods, first class products could be made. (18 references).—P. S.

Some Polish Refractory Materials. (*Refract. J.*, 1957, **33**, Nov., 492–497). A report on fireclays, quartz slate, firebricks, and their uses is given.

Handling of Refractory Materials. (*Mech. Handling*, 1957, **44**, Nov., 656–657). An account of the new installation of the Plibrico Co. Crusher plant with conveyors and dust extractors is described.

Properties of Non-Stoicheiometric Compounds. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Nov.). **Introduction.** J. White. (553–566; discussion, 566–568). A theoretical account of lattice defect theory. **Non-Stoicheiometry at High Temperatures in Systems Containing Iron Oxides.** D. Woodhouse and J. White. (569–579; discussion, 579–580). Large departures from molecular proportions occur in both wüstite and magnetite and in the spinel series with MgO, Al_2O_3, and Cr_2O_3. The boundaries of these phases are determined. **Structure Changes in Some Non-stoicheiometric Oxides of the Transition Elements.** H. P. Rooksby. (581–586; discussion, 586–589). The distortion of the cubic structure of FeO below the antiferromagnetic Néel temperature of — 70° C is affected by Fe concentration and with decreasing Fe deformation is reduced. NiO below 250° behaves similarly. Large effects are produced by impurities as low as 3 mol%. **Some Properties of Refractory Non-stoicheiometric Oxides.** W. J. Kramers and J. R. Smith. (590–605; discussion, 606–607).

Selected Annotated Bibliography of High-Grade Silica of the United States and Canada Through December 1954. M. C. Jaster. (*U.S. Geol. Survey Bull.*, 1019–H, 1957, 609–673).

Investigation of the Alumina Region of the Ternary Alumina–Silica System. I. Systems: FeO–Al_2O_3–SiO_2 and MnO–Al_2O_3–SiO_2. F. Ya. Galakhov. (*Izvest. Akad. Nauk. Otdel. Khimi*, 1957, (5), 525–531). [In Russian]. The boundaries between the mullite and corundum fields correspond with the eutectic points of the system Al_2O_3–SiO_2. The author corrects his previous diagram of the FeO–Al_2O_3 system because (Herzinite)FeO,Al_2O_3 melts without decomposition and not, as he previously supposed, with decomposition.—L. H.

Determining the Impurity Content of Raw Materials Used in the Production of Silica Bricks. O. Vepřek. (*Silikáty*, 1957, **1**, (2), 171–173). [In Czech]. Procedure for ascertaining the presence of aqueous silicates is described. Differential and gravimetric thermal analysis is employed. A method for differentiating between kaolinite and illite is given.—P. F.

Melting Points and Certain Phase Relationships in the System Magnesium Orthosilicate, Magnesium Orthotitanate, Magnesioferrite. M. R. Rao. (*J. Sci. Ind. Res.*, 1957, **16B**, Oct., 444–451). The study of a limited area of the system and an investigation of solid solutions between orthotitanate and magnesioferrite by melting point and X-ray methods is extended to the effects of Fe_2O_3 and TiO_2 in forsterite refractories.

Equilibrium Studies on the System Iron (II)–Oxide–Zirconium Oxide. W. A. Fischer and A. Hoffmann. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 739–743). The system has been studied by thermal analysis, microscopical, and radiographic investigations, and metal–slag equilibria. The results have been collated in a phase diagram iron (II)–oxide–ZrO_2 for the temperature range 1300 to 1800° C.—L. J. L.

A New Method of Evaluating Slovak Magnesite Sinters, and the Application of Experiences Gained with it for Improving Magnetic Separation. Z. Smutný and K. Berka. (*Silikáty*, 1957, **1**, (1), 65–76). [In Slovak]. Shaft kilns are shown to be preferable to rotary kilns in the production of magnesite bricks, even if the rotary kilns are heated with gaseous fuels which do not foul the material with ash. By the choice of the right kiln, which may be made on the basis of experiments of the type described in the paper, productivity and quality can be improved, and by-products otherwise wasted can be recovered. A laboratory method for determining the components of the sinters was developed and utilized for the determination of optimum production conditions.—P. F.

Molybdenum Furnaces. B. E. Vassiliou. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Oct., 509–515). Laboratory furnaces operating up to 1750° C are described.

Note on the Effects Produced by Water-Soluble Salts in Refractory Clay Mixtures. F. G. West-Oram. (*J. Soc. Glass Techn.*, 1957, **41**, Feb., 89–94). Additions of NaCl and Na_2CO_3 to clay–alumina mixtures were examined. After firing, high concentrations of soluble salt were found at the surface.

Electrical Resistance and Thermodynamic Measurements in Chromium (III)–Oxide at Temperatures up to 1750° C. W. A. Fischer and G. Lorenz. (*Arch. Eisenhütten.*, 1957, **28**, Aug., 497–503). The electrical conductivity of Cr_2O_3 at temperatures ranging from 900° to 1750° C has been studied by measuring resistance and thermoelectric force as affected by the partial O_2 pressure of the atmosphere and by adding oxides with high- or low-valency metal ions.—L. J. L.

Calorimetric Studies on the $\alpha \rightleftharpoons \beta$ Transformation of Cristobalite. O. Krisement, H. Schädler, G. Trömel, and K.-H. Obst. (**Arch. Eisenhütten.*, 1957, **28**, Sept., 523–530). The $\alpha \rightleftharpoons \beta$ transformation of cristobalite has been studied by a microcalorimetric method, using a spectrally pure cristobalite powder. The cristobalite was annealed at 1400°–1680° C; crystallization occurred after periods varying from 10 h to 10 days. The tests showed that the $\alpha \rightleftharpoons \beta$ transformation is determined solely by the temperature and not by the duration of transformation.—L. J. L.

The Behaviour of Different Types of Refractories to Thermal Softening under Load. E. Perez Blanco. (*Inst. Hierro Acero*, 1957, **10**, Apr.-Jun., 147–159). [In Spanish]. The author discusses the various specifications for testing, and briefly considers the mechanism of the softening process. Deformation–temperature curves, typical compositions and properties, and brief details of the characteristics of alumina–silica, sillimanite, corundum, silica, semi-silica, carbon, and silicon carbide bricks are given. The magnesite bricks were of German origin, the carbon and semi-silica bricks from England; the rest were of Spanish origin. (17 references).—P. S.

Electric Resistance of Sintered Alumina. R. Bárta, M. Bartuška, J. Hlavač, and S. Procházka. (*Silikáty*, 1957, **1**, (1), 77–83). [In Czech]. The influence of the purity and fineness of the alumina on the specific resistance of sinters was investigated in the range 400–700° C. Alkalies were found to decrease the specific resistance considerably, but small quantities of SiO_2, CaO, TiO_2, Fe_2O_3, and Cr_2O_3 had no significant effect. V_2O_5 also decreases the resistivity, while MnO and Ca compounds tend to increase it. Fine grained sinters have a higher resistivity than coarse grained ones.—P. F.

Comparative Study of Spalling Test Methods for Refractories. J. C. Banerjee and D. N. Nandi. (*Refract. J.*, 1957, **33**, Nov., 488–490). The Indian standard method is compared with a modified B.S.I. process, which is recommended.

The Melting Phase of Firebricks. Part II. The Effect of Iron (III) Oxide and Alkalis on the Formation of Mullite and Glass in Fired Clays. A. K. Bose, H. Müller-Hesse, and H.-E. Schwiete. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 667–670). Systematic investigations have been carried out, by means of the "Internal Standard" method, on formation of crystal and glass in fire clay as a function of the Fe_2O_3 and alkali contents.—L. J. L.

Basic Linings for Electric Arc-Furnaces Producing Low Carbon Stainless Steels. J. Dobrý. (*Hutn. Listy*, 1957, **12**, (10), 907–912). [In Czech]. Tamped dolomite–tar mixtures used for linings were found to be short-lived and to carburize the bath. Various chrome-magnesite bricks were tried and were found to give substantial improvements in performance.

Ladle Bricks for Electric Steel Manufacture. IV. Some Aspects of the Erosion-Resisting Factors of Some Fireclay Materials. U. Ozawa, T. Muto, and S. Tokoro. (*Rep. Gov. Ind. Res. Inst.*, 1957, **6**, Jan., 54–59). Erosion resistance was measured and compared with chemical and mineral components, porosity, refractoriness and macroscopic structure. A ratio of 2 : 3 for $SiO_2 : Al_2O_3$ showed lower erosion resistance and quantities of Fe_2O_3 and TiO_2, but not especially other properties, affected erosion.

Alumina-Chrome Refractories for Ladle Linings. V. A. Bron and P. A. Lande. (**Metallurg*, 1957, (9), 17–18). The Chelyabinsk plant in the Urals was getting only 6 to 10 casts per ladle. Details of the alumina-chrome bricks (77% alumina, 10·8% chrome) used to improve the life are given. These bricks were used in 100-t ladles. Details of wear are given. Some difficulties associated with the use of this type of brick are enumerated but ladle lives of up to 20–22 casts are now expected compared with an average life of 7·6 casts for the fireclay-lined 100-t ladles formerly employed.—B. S.

IRON AND STEEL, GENERAL

Iron and Steel Making. G. Bulle. (*V.d.I.Z.*, 1957, **99**, Oct. 21, 1541–1546). This is an annual survey of developments that have taken place, under the headings of iron ore supplies, ore beneficiation, coke supplies, blast-furnace operation, alternative iron making processes requiring less or no coke, pneumatic steel making plants, vacuum casting, high-speed pouring, continuous casting, and by-products. (51 references).—J. G. W.

The French Iron and Steel Industry within the National, European and World Framework. P. Epron. (*Mét. Constr. Mécan.*, 1957, **89**, June, 515–525). The industry is a basic export and heavy industry dependent greatly on raw materials and transport and it necessitates long term planning. The iron and steel industry within the European Coal and Steel Community will be more and more dependent on iron ore imports.—B. G. B.

Zaragoza Plans the Installation of an Iron and Steel Works. (*Met. Elect.*, 1957, **21**, Nov., 135–136). [In Spanish]. This is planned to exploit the Tierga ores; it will have a production of about 45,000 t annually and requires a capital of 275 million pesetas.—P. S.

Topical Notes on the Swedish Steel Industry. S. L. Wahlström. (*Jernkontorets Ann.*, 1957, **141**, (6), 311–316). Swedish production and exports of iron and steel continued to rise in 1956. The cost of fuel is twice as much as on the Continent, and hydro-electric development is therefore extremely urgent. At present the iron industry consumes 12% of total power produced. Scrap iron is harder to come by since the formation of the European Iron and Steel Community, and measures have been taken to stimulate collection at home. The trend of prices, the probable effects of the European common market, Scandinavian co-operation, research, and technical training are also discussed.—B. K. E.

A Short Description of the Ironworks of Jesenice and Its Installations. K. Rebek. (*Nova Proizvodnja*, 1954, **5**, (3–4), 165–168). **New Extensions of the Jesenice Ironworks.** M. Nikolic. (215–229). The development of the works and the need to transfer some of

them elsewhere without interruption of capacity are described. **Productivity of the Jesenice Ironworks.** H. Bogomil. (271–275). A comparison with other European works is made and improvements since 1945 are described.

Progress in Research and Technique. (*IVA*, 1957, **28**, (2), 53–100). (69–70). (From Annual Report dated 25 Oct. 1956). At Norrahammar Foundry an automatic sand preparing installation now reduces labour and risk of silicosis. (90–96): Fagersta has developed a number of new steels with high fatigue resistance and stress limit. Kallinge have installed a new rotary furnace for fining. Nyby Bruk have put into use a cold rolling mill for stainless steel. Hallstahammar have a new reversible twin rolling mill for cast metal which is largely automatic. An automatic wire rolling mill, controlled by deltameter, is in use at Sandviken. Svenska Rotor Maskiner have developed a new hydraulic gear suitable for motor vehicles and diesel locomotives.

Standardisation of Metallurgical Installations and Buildings. J. Kopecký. (*Hutn. Listy*, 1957, **12**, (10), 865–877). [In Czech]. The development of rationalized standard types of design for structures and equipment used in the metallurgical industry, including complete layouts for works, is discussed. Examples taken from the field of coking, ore preparation by hot and cold methods, production of pig-iron and steel, foundry work, works transport, construction of sheds and buildings, etc. are given. Details of all-encompassing standards for large projects, in which individual items and buildings are listed, are presented.—F. F.

Standardisation in Metallurgical Supply Centre Designs. M. Mendl. (*Hutn. Listy*, 1957, **12**, (10), 892–898). [In Czech]. The need for the establishment of central stores to supply large metallurgical centres with ferrous and non-ferrous stock and other materials is stated, and three projects for such centres are advanced and discussed. The principles of rational design are explained, and proposals are made for standardizing the principal types of shelves. The storage capacity of each centre was visualized to be 5000–25,000 t.—F. F.

Our Works. Klöckner-Hüttenwerk Haspe A.-G. (*Pamphlet*, 1956, pp. 60). An account, with illustrations and diagrams, of the blast furnaces, basic Bessemer plant, O.H. and electric furnace sections, rolling mills, laboratories and testing sections and other departments, is presented.

The August Thyssen Hütte. F. W. Starratt. (*J. Met.*, 1957, **9**, Nov., 1426–1431). An account of the rebuilding and re-equipment of the works with help from the U.S. is described.

Reconstruction of August Thyssen-Hütte. (*Engineer*, 1957, **204**, Nov. 1, 649–650; Nov. 8, 685–686). An account is given of the reconstruction following the dismantling of most of the plant other than the blast furnaces. No. 4 and No. 8 blast furnaces have been reconstructed and some details of their operation are given, brief descriptions of the basic Bessemer, oxygen, O.H., and rolling installations are given, a wide strip hot and a continuous cold mill being constructed, and the power installation and concrete factory are also referred to. Slag is also ground as a fertilizer.

Recent Development of the Steel Industry at Home and Abroad. L. Pietikäinen. (*Tek. Kemian Aikakauslehti*, 1957, **14**, June 29, 213–215). Tonnage of steel produced in 1956 by major producing countries is given. In Finland the output of crude steel was 197,000 tons, an increase over 1955 of 5½%. Mechanical properties of mass produced steel are explained and new methods, including automation, are described. Remarkable progress is reported in the Finnish steel industry.

Development of Iron and Steel in the Hungarian People's Republic. G. Ferents. (*Stal'*, 1957, (11), 1032–1033). A review with output figures.

Development of the Iron and Steel Industry of the [East] German Democratic Republic. R. Stainvand. (*Stal'*, 1957, (11), 1034–1038).

The Iron and Steel Industry of Poland. K. Zhemaitis. (*Stal'*, 1957, (11), 1038–1041). Statistical.

The Condition and Prospects of the Iron and Steel Industry of Czecho-Slovakia. W. Cherny. (*Stal'*, 1957, (11), 1046–1055).

The Development of the Iron and Steel Industry in the Rumanian People's Republic. K. Lonchar. (*Stal'*, 1957, (11), 1042–1045).

The Russian Steel Industry. 1. Russia in the World of Steel. H. W. A. Waring. **2. Management and Labour.** C. Adamson. **3. The Urals Steel Plants.** T. P. Colclough. (*Steel Rev.*, 1957, Apr., 24–48). Illustrated accounts by members of the British Steel Missions.

Progress in the Iron and Steel Industry of the U.S.S.R. During the 40 Years of Soviet Power. B. Ya. Ryabin'skii. (*Stal'*, 1957, (11), 961–964). A review, with statistics of production.

The 25th Year of the Kuznetsk Metallurgical Combine. (*Metallurg*, 1957, (4), 2–39).

Scientific and Research Work at the Zaporozhstal Iron and Steel Plant. G. F. Chub. (*Stal'*, 1957, (10), 957–959). Sinter production, iron making and oxygen blowing of steel, ferromagnetic properties and other topics are briefly noted.

Twenty-Fifth Birthday of Dnyeprospetsstal Plant in the Ukraine. (*Metallurg*, 1957, (10), 1–8). The article refers to the building of this plant at the beginning of the first Five-Year plan and describes some of the latest techniques used there.—R. S.

Iscor Works, Vanderbijl Park, South Africa. (*Blast Furn. Steel Plant*, 1957, **45**, Nov., 1269–1292). A description of the coke ovens, blast furnaces, O.H. plant, blooming, plate and strip mills, pickling and galvanizing lines and services is given.

Steel: World Report. 1. British Steel Plant for India. J. Hennessy. **2. World Steel Production. 3. Steel Consumption per Head. 4. Steel Prices.** (*Steel Rev.*, 1956, July, 12–19). A review of plans for plant construction and an outline of statistics are presented.

Steel: World Report. 1. The Latin American Steel Industry. H. W. A. Waring. **2. Iron Ore from the Orinoco.** W. F. Cartwright. (*Steel Rev.*, 1957, Oct., 48–56). A brief economic review and an account of a visit to the Venezuelan ore fields are presented.

Problems Facing Works Laboratories in the Complex Automation of Ferrous Metallurgy. (*Zavodskaya Laboratoriya*, 1956, **22**, (5), 515–518). [In Russian]. The extensive automation envisaged in the sixth five-year plan for Soviet industry is discussed in relation to iron and steel production. The tasks to be performed by research and works laboratories to assist in the extension of automation to the control of complete works and processes are considered.

Methods and Equipment Used for the Utilisation of Waste Heat in the Metallurgical Industry. R. Kremer. (*Sborník Vědeckých Prací Vysoké Školy Báňské v Ostravě*, 1956, **2**, (4), 87–108). [In Czech]. The theoretical and practical aspects of the problem are reviewed in detail.—F. F.

Automation of Thermal and Technological Processes of the Iron and Steel Industry. V. V. Vorobei and A. M. Zimakov. (*Stal'*, 1957, (11), 1024–1027).

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG-IRON

Efficiency of the Iron Blast-Furnace. J. S. Vatchagandhy, S. Visvanathan, and V. G. Paranjpe. (*Tisco*, 1957, **4**, Oct., 193–198). The authors consider the various factors contributing to blast-furnace efficiency, e.g. percentage iron recovery, coke rates, utilization of carbon as fuel and reducing agent, and are led to the conclusion that the iron blast-furnace is far more efficient than the alternative methods of ironmaking. The authors also discuss other economic factors such as production rates, consistency of iron quality, and material requirements per unit of product, and show that these further strengthen the claim that the blast-furnace is the most economical and efficient ironmaking unit. (11 references).

Blast Furnace Commission. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 7, 1455–1457). Short notes on a conference held in France in Sept. 1956 are given. The subjects discussed were the desulphurization of liquid pig iron and blast furnace assessment.—B. G. B.

Some New Developments in Blast-Furnace Practice. M. Gottwald, R. Kremer, and L. Tomis. (*Sborník Vědeckých Prací Vysoké Školy Báňské v Ostravě*, 1956, **2**, (5), 65–75). [In Czech]. The principles and practice of spray washing of blast furnace gases, in which the gas enters the scrubbing chamber at velocities greater than critical, i.e. leading to turbulent flow, are discussed. In the second half of the paper a comparison is made between Soviet and American methods of automatic blast-furnace control systems based on the differential pressure principle.—F. F.

Recent Progress in Blast Furnace Technique. A. Roos. (*Génie Civil*, 1957, **134**, June 15, 269–277). Blast furnace operation is elucidated in terms of chemical potential and all the reactions taking place are considered. The internal thermal mechanisms are described with notes on radioactive tracer studies and factors in coke consumption are set out and a thermal balance established.

All-Union Conference of Blast Furnacemen and Sinter Plant Operators. (*Metallurg*, 1957, (6), 11–12). The Conference took place at Dnyepropetrovsk in the Ukraine 26 March to 2 April, 1957. 41 reports were presented. 7 out of the 10 papers given at the plenary sessions referred to ore preparation. Some of the main topics at the Conference are mentioned but no details of papers are given.

The Development of the Blast Furnaces of Jesenice. C. Drago. (*Nova Proizvodnja*, 1954, **5**, (3–4), 169–183). An historical account with a description of the last reconstruction with details of output and coke consumption and cost comparisons.

Some Badly Designed Features of the Conveyor Belt Sinter Feed System to the Blast Furnace Bunkers at Cherepovets. V. A. Karasik. (*Metallurg*, 1957, (8), 12–14). Cherepovets is the first Russian plant to feed all raw materials to the blast furnace bunkers by conveyor belts, 32 and 40 in. wide, at 1·6 m/sec. This article mentions some of the difficulties encountered due to some inadequate engineering features.—R. S.

Increasing the Rate of Smelting in Blast Furnaces. M. Ya. Ostroukhov. (*Metallurg*, 1957, (8), 7–10; *Iron Coal Trades Rev.*, 1957, **173**, Nov. 8, 1075–1077). The relationships are discussed between intensity of smelting (tons of iron produced per m³ per 24 h), and coke consumption, amount of fines in the ore charge, time the charge remains in the furnace, amount of gas produced and slag volume. Measures are described which make it possible to achieve a burden throughput time of 5 h with increased intensity of smelting.—R. S.

Use of Charcoal in the Metallurgical Industry. V. N. Kozlov and G. I. Chufarov. (*Procs. of the Inst. Chem. and Met., 2nd ed., Symposium on the Work of the Wood Pulp Chemistry Laboratory, Moscow*, 1955, 5–9). [In Russian]. Methods for the economic use of charcoal and for reducing charcoal consumption in the manufacture of pig iron are described. The bases of charcoal metallurgy are: (*a*) a rational selection of the types of pig iron to be produced with charcoal, both for making special cast irons and for converting to high grade steels in acid O.H. furnaces; (*b*) the use of special low S and P ores naturally alloyed with V, Ti, Cr, and Ni; (*c*) use of high grade metallurgical charcoal of uniform composition, lump size and strength; (*d*) introduction of electric blast furnaces using electricity from steam power stations operating on non-coking coals and peat or from hydro-electric stations.

Optimum Final Temperature of Carbonisation of Wood Pulp to Produce Metallurgical Charcoal. V. N. Kozlov. (100–116). The optimum final carbonisation temperature for wood pulp to produce the maximum yield of non-volatile carbon, maximum strength of the charcoal produced and maximum yield of liquid distillates (acids, alcohols, esters, etc.) is 350 to 380° C. Various existing methods are criticised.—R. S.

Considerations on the Energy Balance of a

Blast Furnace Plant. J. Szczeniowski. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 8, 1651–1669). A detailed survey of energy production and consumption in a blast furnace plant is presented. A series of appendices deal with: stove and blower efficiency, consumption of energy in gas cleaning, burden preparation, and in the blast furnace.—B. O. B.

Method of Correcting Blast Furnace Operational Conditions. A. N. Red'ko. (*Metallurg*, 1957, (9), 3–5). [In Russian]. When operating a blast furnace, particularly with unprepared burdens, the ore charge frequently varies. This affects thermal conditions and slag basicity and the Si and S contents of the iron. A method of correcting the ore charge, consumption of limestone and thermal conditions is described. The following factors are utilized: relationship between coke consumption and Si content of the iron, the ore/coke ratio, relationship between blast temperature, blast humidity, CO_2 content of the gas, slag volume, and coke consumption.—R. S.

Controlling Blast Furnace Operations According to the Variation in Static Pressures. P. G. Baranovskii and A. A. Kargin. (*Metallurg*, 1957, (9), 5–7). By determining the total difference in static pressures in the zone extending from the tuyeres to the throat and in any specific sections of this zone, the variations in the gas permeability of the burden can be estimated and it is possible to establish not only the locations of the sources of hanging but also to evaluate the possibility of hanging. The instrumentation used is described.—R. S.

Ravenscraig Starts: Colvilles' New Plant Now Working. (*Iron Steel*, 1957, **30**, Sept., 445–448). The new Ravenscraig plant of Colvilles Ltd. has recently come into production. Brief details are given of the coke ovens and by-product plant, blast furnaces and ancillaries, gas-cleaning plant, sintering machine, melting shop, gas disposal, power station, and communications.—G. F.

Soviet Blast Furnace Production. I. A. Nekrasov. (*'Stal'*, 1957, (11), 965–968). A review article for the last 40 years.

Oxygen-Enriched Blast for Blast Furnaces. F. A. Khil'kevich, B. L. Lazarev, and S. V. Bazilevich. (*Metallurg*, 1957, (6), 3–7). Details are reported of trials in 1957 at the Novo Tagil plant (Urals) with 96–98% pure oxygen. Output of the O_2 plant is 10,000 m³/h. The amount of O_2 in the blast is 24%. Practice for the production of steelmaking pig iron and of ferro-manganese is described.—R. S.

The Smelting of Low Manganese Pig Iron in South Russian Blast Furnaces. V. P. Onopriyenko, B. N. Starshinov, N. M. Kharchenko, and A. A. Babii. (*Metallurg*, 1957, (9), 32–33). In the production of pig iron containing 1·5 to 3·5% Mn, 60 to 70% of the Mn in the burden is lost in the slag and flue dust. Experiments at one plant with increasing slag basicity are described. Details of optimum slag basicity, blast temperature, blast humidity and CO_2 content of the gases are studied as major factors in the production of low-Mn pig iron.—R. S.

A Mathematical Method of Determining Coke-Rates in the Production of Pig-Iron in the Blast-Furnace. M. Kadlec. (*Sborník Vědeckých Prací Vysoké Školy Báňské v Ostravě*, 1957, **3**, (1), 79–95). [In Czech]. Coke rates were calculated by the methods of A. N. Ramm, A. P. Liuban, and J. Šárek, and compared with those known to be required in practice. It is shown that Šárek's nomographic method is both the simplest and most accurate of the three. Šárek's nomogram appeared in Vol. 5 of *Hutnické Aktuality*, published in Prague.—P. F.

Air Flow Through a Blast Furnace as Described by a Plant Visitor. (*Blast Furn. Steel Plant*, 1957, **45**, Nov., 1302–1304). Power used, blowers, pressures, and gas washers are reviewed. The visit was to the U.S. Steel Corp. Steel and Wire Division.

Reconstruction of Newcastle No. 2 Blast Furnace. H. R. Shaw. (*B.H.P. Rev.*, 1957, **34**, Aug., 20–21). An account of the day-to-day procedure of rebuilding is given.

Tar-Impregnated Blast-Furnace Ramming Materials. J. Šárek. (*Sborník Vědeckých Prací Vysoké Školy Báňské v Ostravě*, 1956, **2**, (4), 3–11). [In Czech.]. Tar-impregnated ramming materials used for ramming the base of blast furnaces are classified, and experiences gained in using them are discussed. The various possibilities which might have led to the occurrence of observed break-throughs in blast-furnace bases are reviewed, and some ways of improving the use of coke-type ramming materials are suggested.—P. F.

Methods of Speeding Up Blast Furnace Repairs. V. N. Mash'yanov. (*Metallurg*, 1957, (3), 8–10). Rapid major repairs of a 930 m³ Chelyabinsk blast furnace are described. A scraper arrangement for removing debris from the stack and a special crane for assembling the coolers are illustrated. The use of internal, suspended, multi-stage scaffolding in the stack for lining and of an air-hardening solution consisting of 80% fire-clay powder, 5% clay, and 15% alumina with an addition of water-glass are reported.—R. S.

Blast Furnace Charge Level Indication by Gamma Rays. A. Rexroth. (*Giesserei*, 1957, **44**, Nov., 695–697). The intensity of γ-radiation after passing through the furnace will be less if the charge is in position than if the furnace is empty. Apparatus to indicate the charge level in the furnace, and making use of this principle, is very briefly described, and operating experience is reported.—L. J. L.

Carbon Linings Stand Up To Long Furnace Campaign. (*Iron Age*, 1957, **180**, Aug. 29, 74). The condition of the all-carbon hearth lining of a blast furnace at U.S. Steel Corp., which has been in service for 11 years and made over 3 million tons of iron, is described. The side wall bricks were in excellent condition; iron had penetrated under the 2 ft thick bottom. Construction was in 4 × 11 × 18 in. bricks, laid up to the cooling staves.—D. L. C. P.

A Study of the Wear of Blast-Furnace Brickwork by Means of Radioactive Isotopes. J. Holzhey. (*Neue Hütte*, 1957, **2**, Nov., 665–670). The results of experiments on an industrial scale are reported. The principles of measurement, the type of radioactive source, their arrangement in the brickwork, and the determination of their radioactivity, are explained. Preliminary conclusions based on results to date are reported. Some observations are made on radiation in blast furnaces and the problem of processing radioactive pig iron is discussed.—L. J. L.

Continuous Refining of Pig Iron in the Blast Furnace Runner with the Use of Pure Oxygen. P. Leroy and R. Simon. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, (8), 1623–1630; *Rev. Mét.*, 1957, **54**, Oct., 793–812). The blast furnace runner is composed of porous blocks of special design through which O_2 is blown as the pig iron from the furnace flows down the runner. The prerefining runner is about 15 feet long and the porous blocks can easily be replaced when worn. The most important result obtained is that it is possible to desiliconize pig iron continuously in the absence of the red fume normally associated with desiliconizing with oxygen. Blowing tests are reported in which charges of Si and Mn are shown in relation to oxygen volume and addition of lime. The slag was also examined and O_2 balances drawn up. Addition of mill scale and temperature effects were also investigated in relation to Si and thermochemical balance indicated.

Repair of the Big Bell in a Blast Furnace. V. A. Karasik. (*Metallurg*, 1957, (5), 8–9). The top charging gear of the No. 2 blast furnace at Cherepovets (east of Leningrad) was designed for high top pressures of 1–1·5 atm. but the gas valve was somewhat smaller in diameter and rather longer than the standard type. After seven months' operations, gas was found to be leaking between the bell and hopper. Details of damage to the bell are illustrated diagrammatically. Methods of welding up the defective parts are described.—R. S.

Influence of High Pressure on the Decomposition of Ferrous Oxide. V. J. Arkharov and D. K. Bulychev. (*Doklady Akad. Nauk S.S.S.R.*, 1957, **113**, (4), 791–794). Experiments were carried out on wüstite at 400–590° C at ordinary pressure and at 10,000 kg/cm² pressure. The products were studied chemically and by means of X-rays. The results show that the products of decomposition of wüstite obtained under pressure contain more iron than those obtained under normal pressure. It is also concluded that pressure slows down decomposition and lowers the triple point.

The Effect of Pressure on the Reduction Process of Metal Oxides by Carbon. E. Iwanciw. (*Arch. Hutn.*, 1953, **1**, (2), 131–183). [In Polish, with English and Russian summaries]. A general consideration of the effects of $C \rightarrow CO \rightarrow CO_2$ reactions on the reduction of MO.

The Reactivities of Iron Oxides. A. Roos. (*Chim. et Ind.*, 1957, **78**, Sept., 206–213). Oxide structure and its relation to reducibility are reviewed. Wolkenstein's theory of the action of gases on crystal lattices is discussed and applied to gas-phase reduction of iron oxides in the blast furnace and solid phase reduction in the electric furnace. The difference in reducibility between natural oxides and pre-reduced ores is ascribed to the semi-conductor structure of the former.

Determination of Optimal Conditions for Reducing Metal Oxides with Carbon. E. Iwanciw. (*Arch. Hutn.*, 1955, **3**, (1), 131–153. Relationships of the metal oxide to CO and the $C+CO_2$ reaction are formulated on various assumptions. The direct reaction with solid C is neglected and pressure effects are brought in and the pressure for maximum reduction rate and the optimum distance from equilibrium for fastest reduction are derived.

Rate of Desulphurisation of Molten Iron by Slag under Reducing Conditions. T. Saito and Y. Kawai. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 170–173). [In Japanese]. Rates of transfer of sulphur across a slag–metal interface were studied in the range 1440–1570° C, using ^{35}S as a tracer. The net rate of transfer from metal to slag increases with increasing slag basicity and temperature. For high-viscosity slags the transfer could be interpreted as a first-order reaction.—K. H. J.

Studies on the Desulphurisation of Molten Pig Iron by Manganese. I. Mn–S Equilibrium in C-saturated Molten Iron. 1. K. Sano and M. Inouye. (*Tetsu to Hagane*, 1957, **43**, May, 517–522) **2.** (June, 623–627). [In Japanese]. Thermodynamical data for the Mn–S equilibria between 1200° and 1500° C are obtained and shown to agree with those of Oelsen. Data are also given for the effect of dissolved sulphur on the solubility of carbon in iron.—K. H. J.

An Efficient Method of Desulfurizing Liquid Pig Iron. B. Trentini, L. Wahl, and M. Allard. (*Trans. Amer. Inst. Min. Met. Eng.*, 1957, **209**; *J. Met.*, 1957, **9**, Sept., 1133–1139). A description is given of a method of desulphurising liquid pig iron which entails blowing powdered lime into the metal through immersed tuyeres by means of a neutral or reducing gas stream. The principle of the process is described and results obtained are discussed. The process is rapid and efficient; the sulphur content can be reduced from 0·3% to 0·003% in 3–4 min.—G. F.

The Thermodynamics of the Dephosphorization of Iron. I. Yu. Kozhevnikov and L. A. Shvartsman. (*Doklady Akad. Nauk S.S.S.R.*, 1957, **113**, (2), 376–379). Radioactive phosphorus was used for the study of the equilibrium of P between metal and slag. This method allowed the calculation of the thermal effect and the entropy of the dephosphorization reaction for a slag of a definite composition. The influence of the nature of ions and their sizes is also discussed.—S. I. T.

Further Investigations into the Dephosphorisation of Iron with Calcareous Slags. G. Trömel and H. W. Fritze. (*Arch. Eisenhütten.*, 1957, **28**, Aug., 489–495). The tests reported have shown that the phosphorus content of iron under slags saturated with lime increases with increasing temperature. In the presence of silicic acid the content was found to be lower, and the rate of increase with increasing temperature was higher. The O_2 content of metal under lime–phosphate slags was also found to increase with temperature.

Low-Shaft Blast Furnace Holds New Promise. F. W. Starratt. (*J. Met.*, 1957, **9**, Nov., 1432–

1434). Notes on pilot plant and the design of a Troisdorf furnace with briquetting plant for erection at Klöckner Mannstaedt-Werke G.m.b.H. are outlined.

High Temperature Blast Furnace Stoves. Yu. I. Gokhman. (*Metallurg*, 1957, (9), 8–10). Of the various methods of increasing blast temperature, the most efficient is to increase the temperature of combustion beneath the dome. This temperature was increased by 350° C and enabled the hot blast temperature to be raised by 300° C. The authors describe the necessary refractory lining in the different parts of this type of hot blast stove.—R. S.

Complex Automation of Blast Furnace Stoves at Kuznetsk (Siberia). (*Metallurg*, 1957, (6), 8–11). The heating of the stoves, temperature and moisture content of the hot blast and stove valve reversal were automatically controlled. Details are illustrated and described. The automatic control of the stoves is effected by a single system of only 40 mechanisms.

Blast Furnace Equalising Valves. D. A. Storozhik. (*Stal'*, 1957, (10), 874–882). The need for coupled valves with built-in electric drive is stressed. Complete diagrams of this valve are given.—R. S.

PROPERTIES, TREATMENT, AND USE OF SLAGS

The Chemical Theory of Slag Structure. V. A. Kozheurov. (*Zhur. Fiz., Khim.*, 1956, **30**, Feb., 295–304). Calculations of activities of binary and ternary solutions are compared for regular solutions and for formulæ considering short range order. The formation of compounds is seen to be an approximation to short range order. Quantitative computations are only nearly correct when mixing energies are small, and when the regular solution theory is used with correct selection of heat of mixing the results are very near to those involving short range order and are reliable enough and convenient for practical use, particularly for multicomponent systems.

Petrography of Metallurgical Slags and Clinkers. V. V. Lapin. (*Trans. Inst. Geol. Ore Depos. and Akad. Nauk SSSR*, 1956, No. 2). This is a volume of 323 pages, with 21 pages of bibliography, 19 plates and numerous text figures, giving a detailed description of slag minerals, supported by chemical analyses and optical and X-ray data, and slags belonging to the following groups of metal industries: iron, iron alloys, steel, copper, nickel, lead, tin, and others.—S. I. T.

New Types of Solid Solutions in Titanium-Rich Slags. A. V. Rudneva, M. S. Model', and T. Ya. Malysheva. (*Doklady A.N.*, 1957, **115**, (1), 141–144). Optical and X-ray studies of titanium-rich silicate slags have shown the presence of two series of solid solutions: $2MgO,TiO_2$–$2FeO,TiO_2$ and (Fe,Mg,Mn)O, TiO_2–Ti_2O_3. The common silicate mineral in these slags is titano-augite, the fine structure of which is characterized by chains of anion radicals $(Si,Al)_2O_6$.—S. I. T.

The Composition of the Anosovite Group of Minerals. A. V. Rudneva and T. Y. Malysheva. (*Doklady A.N.*, 1957, **115**, (4), 787–790). The principal mineral phase in titanium-rich slags is anosovite whose generalized formula is $m[(Ti,Al,Fe)_2O_3.TiO_2]n[(Ti,Mg,Fe)O,2TiO_2]$. Chemical analyses of anosovite, of the glassy residue and of the corresponding slags show the Al_2O_3 tends to concentrate in anosovite, while the distribution of MgO, MnO, and Fe_2O_3 show rather complicated relations.—S. I. T.

Investigation on the Utilization of Indian Iron Blast Furnace Slag. S. K. Chopra, K. Syamala Rao, and N. K. Patwardhan. (*Journal of the National Buildings Organisation*, 1956, June-Sept., 56–59). The use of wet ground slag as a substitute for cement in concrete is described.

Selection and Suitability of Blast Furnace Slag as Road Ballast. P. Hüttemann. (**Stahl u. Eisen*, 1957, **77**, Oct. 17, 1436–1442). The author compares the properties of natural stone with blast furnace slags and describes a number of test methods. The relation of strength to chemical composition is shown by means of ternary CaO–Al_2O_3–SiO_2 diagrams. Visual selection of the slags is greatly facilitated by colour photography.—T. G.

DIRECT PROCESSES

Economics of the New Iron Ore Reduction Processes. E. C. Wright. (*Met. Prog.*, 1957, **72**, Oct., 99–104). The H-iron and other sponge processes are considered. It is calculated that they require $> 4 \times 10^6$ Btu/ton more than the conventional blast and O.H. furnaces and so must be located where electricity or gas are cheap and coke is dear. Capital costs are about the same per t per year.

Sweden: Iron Powder to Rolled Steel in One Operation. Bo Kalling, S. Eketorp, and S. Backstrom. (*J. Met.*, 1957, **9**, Nov., 1440–1444). An account of the Stora Powder Steel Process is given. Oxygen-blown low-Si pig-iron is used, granulated in air–water, mixed with an ore concentrate and heated in a steel box at 1100° C until decarburization is complete when the hot box is rolled in an ordinary mill.

Production of Rolled Steel Direct from Pig Iron Powder. B. Kalling, S. Eketorp, and S. Backström. (*Jernkontorets Ann.*, 1957, **141**, (6), 317–331). By a new process rolled steel is produced from pig iron powder without first smelting the latter. The powder mixture is packed in a box of thin sheet and then decarburized and rolled at 1100° C into sheet. The process is described in detail. The quality of the steel is comparable to electric furnace steel. An advantage is the high iron recovery—110% rolled steel of pig iron weight. Preliminary results show considerable saving in production costs over other methods. A suggested layout of plant for the process is illustrated with a diagram.—R. K. E.

New U.S. Developments in Direct Reduction. A. Hegarty. (*Iron Steel*, 1957, **30**, Oct., 483–485). The author describes three current American investigations into the direct reduction of iron ore. They are: (1) the H-iron process, based on the ability to produce low-cost hydrogen from crude oil or other common fuels by a partial oxidation process; (2) a process for continuous gaseous reduction of ore in a fluidized bed system, at South Chicago plant of United States Steel Co.; (3) the Esso–Little process, based upon partial combustion of natural gas with air to essentially CO and H_2.—G. F.

Direct Reduction of Iron Ore. V. F. Knyazev. (*Metallurg*, 1957, (10), 32–35). This article reviews various well-known methods of direct reduction and states that these methods are being developed in Russia to produce complex ferro-alloys from naturally alloyed ores.—R. S.

An Experimental Study of the Production of Sponge-Iron in 26% Chromium Cast-Iron Containers. T. D. Le Souza Santos. (*Bol. Assoc. Brasil Met.*, 1957, **13**, Apr., 67–128). [In Portuguese]. A comprehensive study of the process of ore reduction and its subsequent carburization in 26% chromium cast-iron containers is reported. The retorts were cycled for 8 to 27 h in the range 850–1050° C in a furnace of 150 kg sponge iron capacity, and were charged with briquettes of Jacutinga haematite ore (68·7% Fe, 0·29% SiO_2, 0·076% P) and powdered coal (initially about 62% fixed carbon, and 21% ash). The results enabled the determination of (*a*) the relationship of the velocity of recession of the reduced zone/non-reduced zone interface to the main variables, (*b*) the influence of these variables upon the percentage reduction, (*c*) their influence on the carburization of the sponge, (*d*) the dimensional variation of the sponge-iron with temperature, and (*e*) the influence of the coal composition. (The main variables were the briquette diameter, reduction time, temperature, particle size, and composition of the coal). Confirmatory trials resulted in 99·2% reduction (97·2% Fe, 0·18% C) in 20 h at 1000° C with an average consumption of 387 kg coal per t of sponge produced. The containers of 33·6 l. capacity, corresponding to 15·55 kg sponge, appear to have an average life of about 32 cycles. (15 references).—P. S.

On the Feasibility of Producing Spongy Iron in Periodically Operated Oven Chambers of the Coke Oven Type. M. S. Kurtschatow. (*Neue Hütte*, 1957, **2**, Nov., 671–678). The results are reported of laboratory experiments on the production of spongy iron in the form of a concentrated firm cake by the reduction of iron ores of varying reducibility. The effect of various solid fuels and of pre-treatment of the ore on the quality of the product and on the composition of the gaseous phase has been determined. The production of spongy iron on an industrial scale in ovens similar to coke ovens is pronounced to be feasible.—L. J. L.

Rotor Steelmaking Process. R. Graaf, W. Dick, and L. von Bogdandy. (*J. Met.*, 1957, **9**, Nov., 1435–1439). A summary from published articles.

Refining by Oxygen in the Rotary Converter by the Kaldo-Process. B. Kalling and F. Johansson. (*Stahl u. Eisen*, 1957, **77**, Sept. 19, 1308–1315). The Kaldo rotary converter is described. Its capacity is 30-t, its internal dia. 2·5 m, it rotates during refining at 30 r.p.m. and is tilted down to 20° with the horizontal. The converter is designed for blowing phosphorus-rich iron with oxygen. The quality of the steel is similar to O.H. steel. Design details, operation, quality of the steel produced, heat balance, yield, service life, etc. are described and discussed in detail.—T. G.

Steelmaking Plans For Tomorrow. P. M. Unterweiser. (*Iron Age*, 1957, **180**, Sept. 19, 139–144). The following have become potential industrial processes in the last year; they are described, and their value appraised. 'H-Iron' process for reducing ore fines with hydrogen to produce iron; 'Cyclosteel' process using ore fines, pulverized coal and oxygen to produce steel; the 'Diamond Alkali' and 'IRSID' desulphurization processes, which employ caustic soda and lime respectively in different types of reactor; continuous casting.

PRODUCTION OF STEEL

Some Interesting Cases Submitted to the Steel Information Centre. W. Küntscher. (*Neue Hütte*, 1957, **2**, Nov., 678–685). The slag reduction process; the oxidation of steel during tapping and casting; the choice of steel for particular applications; high-quality constructional steels; and problems of collaboration with steel consumers are surveyed.

Statistical-thermodynamic Studies on Fundamental Reactions Concerning Steelmaking. X. On the Configuration of Fe–O Molten Slag and its Interaction with Gaseous Oxygen. S. Takeuchi and K. Furukawa. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 165–169). [In Japanese]. A conjectural model for the ionic composition of Fe–O melts is suggested, and used to calculate the partition function and the equilibrium relation between slag composition and the pressure of O_2 in the gaseous phase. The theoretical results are in good agreement with measured values over a wide range of pressure and temperature. (11 references).—K. E. J.

Review of Steel Making Processes and Alloyed Steels. F. Sommer. (*V.D.I.Z.*, 1957, **99**, Oct. 21, 1517–1525). This review, written for engineers, contains descriptions of the traditional steelmaking processes and also of the LD and Rotor processes and pouring methods, an outline of the structures encountered, and brief descriptions of the principal types of alloy steels together with indications of their best-known uses.—J. G. W.

Raw Materials for Steelmaking. (*Steel Rev.*, 1956, July, 32–39). The trade in scrap and ore is reviewed and imports and internal movements of iron ore are shown on maps in general statistical terms.

Scrap Iron in the Iron Industry. G. Lindblom. (*Tek. Tidskr.*, 1957, **87**, Oct. 29, 921–924). Types of furnaces and their ability to deal with scrap iron are listed. The uses of old and new scrap and chemical composition, i.e. other components of scrap iron such as sulphur and non-ferrous metals, are dealt with.

Handling of Scrap in Industry. L. Hedström. (*Tek. Tidskr.*, 1957, **87**, Oct. 29, 927–930). Factories where scrap iron is liable to accumulate should appoint a responsible organizer, arrange for scrap yards, sorting and preparation in sizes suitable for foundries to deal with. Scrap from demolitions or replacements of old

machinery differs from that caused by current factory operations (e.g. by lathes) and can be dealt with differently. The author finally gives an account of the sale of scrap.

Classification of Malleable Steel Scrap. L. Hedström. (*Tek. Tidskr.*, 1957, **87**, Oct. 29, 925–927). Scrap from outside sources is classified according to degree of adulteration. A main division is between alloy and non-alloy steel; other adulterations give another large group. A book, "The Scrapbook," is referred to which gives the market value of scrap according to a number of subdivisions.

Treatment of Scrap Metal. E. Lindberg. (*Tek. Tidskr.*, 1957, **87**, Oct. 29, 931–934). The installations and processes at a scrap metal dealer's yard are described and illustrated. Taking items to pieces, sorting, pressing, loading, and mechanization are dealt with.

Large Steel Mill Oxygen Plant. (*Ind. Heat.*, 1957, **24**, Sept., 1742, 1744, 1746, 1748, 1900). The plant at U.S. Steel, Duquesne works, for ferromanganese production is described. It produces 500-t daily and is expected to increase Fe–Mn production by > 25%.

Efficient Use of Oxygen in Steel Production. V. A. Rozhkov. (*Metallurg*, 1957, (7), 12–15). R. reports on the use of O_2 in the flame of the 185-t furnaces at the Zaporozhe (Ukraine) plant and in the 370-t furnaces at Nizhni Tagil (Urals). Data on the production of certain grades of steel with and without O_2 are compared.—R. S.

Oxygen in British Steelmaking. D. J. O. Brandt. (*Steel Rev.*, 1957, Jan., 43–48). A review of developments in the use of oxygen.

Production of Steel in the U.S.S.R. D. A. Smolyarenko. (*Stal'*, 1957, (11), 968–976). Production statistics are shown graphically and 18 months' experience with a 500-t O.H. furnace is described. Dimensions of 500 and 250-t furnaces are compared and details of construction are given, and of twin ladle casting, use of O_2, automation, continuous casting, refractories, and improvement of metal quality. The problems requiring solution are indicated. Continuous casting is now carried on in 8 units with ladles from 50–130 t. Plans are being made to cast slabs < 6 in. thick and up to 5 ft wide and blooms up to 12 in. × 12 in. and methods for rapid changing of the mould are being developed. Much data on refractories are given, and organization of O.H. plants as units of 2–3 with a single crew is mentioned.—R. S.

Furnaces for Special Steel Making. G. Grenier. (*Usine Nouv.*, 1957, Oct., 581–583). A general review with compositions of charge and times of heating, furnace capacities, oxygen consumption etc. taken from the literature. (15 references).

Free Energy Changes for Oxidation Reactions of Materials Important in Steelmaking Processes. J. Bochenek and E. Ptak. (*Arch. Hutn.*, 1954, **2**, (1), 58–69). Free energy values are evaluated taking into account allotropic changes where these occur for Al, Ca, Cr, Mg, and Ni. Values are obtained for the range 1700–2000° K and related to equilibrium O_2 pressures.

Plant for Steel. (*Steel Rev.*, 1957, Oct., 30–39). An account is given of developments in hand and foreshadowed in Britain.

New Scottish Steel Works. (*Elect. Rev.*, 1957, **161**, Aug. 9, 235–236). An account of Ravenscraig with special reference to power.

The Development of High Quality and Refined Steel Production at Jesenice Ironworks. T. Vasilij. (*Nova Proizvodnja*, 1954, **5**, (3–4), 184–193).

Steelmaking "Down Mexico Way." S. Chavez. (*Ind. Heat.*, 1957, **24**, Sept., 1795, 1796, 1798, 1800). The Piedras Negras steel plant is briefly described. A small blast furnace with 8 ft 6 in. hearth producing 140 t daily, originally intended for charcoal and rated at 80 t per day, two O.H. furnaces producing 65 and 85 t respectively, and a rolling mill are installed.

On the Basic Pneumatic Processes of Steelmaking. P. Coheur and H. Kosmider. (*Blast Furn.*, 1957, **45**, Oct., 1131–1139). A review of the Basic Bessemer process and alternatives such as the L.D., Kalling, and Tropenas modifications is presented. (62 references).

New Horizons in Thomas Steel Making. M. Allard. (*Mém. Soc. Ing. Civils France*, 1957, **110**, May-June, 194–199). Future developments in steelmaking are discussed and in particular the recent advances in the basic Bessemer process.—B. G. B.

Developments in Converter Production. S. G. Afanas'ev. (*Stal'*, 1957, (11), 982–987). A review of developments since 1930 is presented. Mechanization of cold repairs and methods of changing the lining are noted. Advantages of the process, duplexing, Si and Mn removal from pig iron and the production of a semi-product with 3% Cr and 1% Ni from a naturally alloyed iron for the O.H. are described. Phosphatic ores found in Kazakhstan have increased the importance of basic Bessemer operations and the use of O_2 is being developed.—R. S.

Oxygen-Enriched Bessemer Steels. A. Krüger. (*V.D.I.Z.*, 1957, **99**, Nov., 1604–1610). The drawbacks and advantages of Bessemer and O.H. steels for various applications are discussed under the following headings: the basic Bessemer process; improved converter steels; properties and uses of soft converter steels; and other basic Bessemer steels.—L. J. L.

Effecting Dephosphorization Before Decarburization in the Refining of Steel with Pure Oxygen. H. Kosmider, H. Neuhaus, and H. Schenck. (*Stahl u. Eisen*, 1957, **77**, Sept. 19, 1277–1283). The authors describe two methods: (*a*) The combined blowing process in which oxygen is blown at low pressure on to the surface of the charge, whilst the cross-section of the bottom-plate holes was markedly reduced. (*b*) The buffer-slag oxidation method in which contact between gaseous oxygen and molten metal is avoided. The reactions take place via the slag. This method is described in detail and the results obtained presented in diagrams and discussed.—T. G.

Experience and Knowledge Gained in the Blowing of Basic-Bessemer Steel with Pure Oxygen. F. A. Springorum, K. G. Speith, O. Därmann, and H. vom Ende. (**Stahl u. Eisen*, 1957, **77**, Sept. 19, 1284–1296). Using the LD-process the elimination of phosphorus proved difficult and could be attained only by prolonged blowing. The authors describe a modification of the LD-process which they carried out for obtaining low-P melts. The various processes employed and the reactions involved are discussed at length. Results obtained are presented in many graphs and diagrams.—T. G.

On Overheating Bessemer Steel. V. A. Fuklev and L. K. Grakhov. (*Lit. Proizv.*, 1956, (10), 9–10). [In Russian]. The authors do not quite agree with the statement that overheating is due to the additional heat coming from the oxidation of CO to CO_2. For economical overheating of Bessemer steel it is essential to reduce the temperature losses to a minimum. In practice the heat required to yield 1 t of metal can vary from 60,000 cal to 250,000 or more.—L. H.

Trials with Various Grades of Steel-Plant Limestone in the Basic Bessemer Converter. K. E. Mayer, H. J. Därmann, G. Trömel, and K. H. Obst. (*Stahl u. Eisen*, 1957, **77**, Oct. 31, 1614–1618). Trials with sieved limestone showed that limestone of size 8–40 mm is best suited from the point of view of heat balance. By limiting the size to 40 mm a large quantity of heat becomes available which can be used for melting down scrap or for increasing the addition of ore. Fine limestone below 8 mm should be made into briquettes, possibly with fine ore as pitch should not be used in great quantities.—T. G.

Studies on the Properties of Converter Smoke as a Basis for Spectrographic Control of the Basic Bessemer Process. F. Wever, W. Koch, H. Lüdering, H. Knüppel, K. E. Mayer, B. A. Steinkopf, and G. Wiethoff. (**Stahl u. Eisen*, 1957, **77**, Oct. 17, 1451–1459). Microanalysis and electron-microscopical, X-ray and electron-diffraction methods were used for a study of the constitution of converter smoke. The reaction products are formed at points of max. temperature, these condense to fine droplets of 10–100 mμ dia. above the bath. The smoke consists mainly of FeO with manganese and phosphorus. The grain-size of the smoke increases with increasing blowing time indicating a change in composition. Quantity of fine smoke and manganese content are related, the maximum coincides with the "second manganese hump."—T. G.

The Fight Against Brown Fumes when Blowing the Bath with Oxygen. G. S. Sel'kin and N. I. Zadalya. (*Stal'*, 1957, (10), 884–887). An effective means of dust elimination is the moistening of the O_2 with water in a ratio of 0·5–0·9/1. This has no harmful effect on the steel. Humidified O_2 can be used even at an early stage in melting, say an hour after charging hot metal. Productivity is increased 24% without reducing furnace life over the process without O_2. Fuel consumption is reduced by 25%. Moist O_2 can also be used for the pre-refining of pig iron. Details of consumption are given and conditions at the top of the stack are shown, also photographs of the O_2–H_2O jet at various humidities.—E. S.

Loss of Temperature of Steel Melts After Tapping. H. Neuhaus, H. J. Kirschning, and W. Münstermann. (*Stahl u. Eisen*, 1957, **77**, Nov. 14, 1660–1666). This is a supplement to the paper by H. Kosmider and the authors, *ibid.*, 1957, **77**, 133. Optical and thermo-electric methods of temperature measurement are compared, and the various factors that affect the accuracy of the optical method discussed. 22-t charges from a basic converter fall about 80° C in the 18 min from the end of blowing to the beginning of pouring.—T. G.

The LD Process. H. Hauttmann. (*Jernkontorets Ann.*, 1957, **141**, (6), 332–349). The need for a large scale steel process independent of scrap iron to expand Austrian steel production has led to the LD process. Pig iron is fined with an oxygen stream at right angles to the surface, and further details of procedure are given. VÖEST have three LD converters, each of 30 tons capacity, which produce 840,000 tons of steel per annum, and the process is also being adopted elsewhere. Costs are decidedly lower than in the O.H. process as a table shows. LD steel is equal, and in many ways superior, to O.H. steel, and the process can be used for low alloy steel.

The Mechanisms Involved in Top Blowing. R. Hammer, T. Kootz, and J. Sittard. (**Stahl u. Eisen*, 1957, **77**, Sept. 19, 1303–1308). The forces of a laminar and turbulent oxygen jet on the movement of the surface layers of the melt in top blowing of iron are described and illustrated using models.—T. G.

Review of Methods Employed in Blowing of Phosphorus-Rich Iron with Oxygen. H. Rellermeyer, H. Knüppel, and J. Sittard. (**Stahl u. Eisen*, 1957, **77**, Sept. 19, 1296–1303). The authors discuss the difference in the dephosphorization mechanism in an O.H. furnace and in the LD-process. They deal with the movement of the molten metal in the latter and compare blowing with one jet and three jets. Combined blowing from top and bottom is also discussed, as well as the Perrin effect in top blowing and an appraisal of all processes with a view to finding the process which will prove best in the future.—T. G.

Economic Significance of the LD-Process. J. Oberegger. *V.D.I.Z.*, 1957, **99**, Oct. 11, 1499–1503). The advantages of the LD process are considered against the background of scrap shortage indicated by statistics of world production of steel, in terms of a comparison with other processes of its consumption of energy, furnace life, labour, output, and capital costs. The uses of the LD process are then outlined.

Use of Sinter in the Open Hearth Furnace. N. A. Vecher, A. A. Lebedev, and N. D. Kornesv. (*Metallurg*, 1957, (6), 17–19). Due to the shortage of ore supplies, sinter formed 66·3% of the oxides charged in the O.H. plant at Nizhni Tagil (Urals). It was used in the production of rimming, killed, carbon, and alloy steels in acid, and basic 140, 260, and 380-t furnaces. Details of the physical and chemical properties of the sinter are given. Consumption of sinter in the charge is higher than that of ore. More slag is made. Tap-to-tap time is reduced by 12 to 15 min. For a given P content in the iron, lower P is obtained in the steel when sinter is charged than when ore is charged (P content of the steel is 0·002–

0·012% lower). Sinter heats accelerate carbon elimination during the ore boil. Details of heats made with and without sinter are tabulated.—R. S.

The Driving Rate of Open-Hearth Furnaces. R. W. Evans *et al.* (*J.I.S.I.*, 1958, May, **189**, 19–28. [This issue].

Canada's Largest Tilting Open Hearth. (*Can. Metalw.*, 1957, **20**, Oct., 34). A 225-t furnace installed by the Maritime Steel Co. is shown.

The Problem of Cast Iron Ingot Moulds. G. Stanciulescu. (*Met. Constr. Masini*, 1956, **8**, (11), 51–56). [In Rumanian]. A detailed study of the theoretical and practical considerations which can increase the life of these moulds is outlined, 352 normal conical and inverse conical moulds have been investigated in various plants. 219 of these were cast in the plants and 133 were cast under the control of the investigator according to the suggestion of the State Institute. Whilst the former withstood on the average 37 teemings representing 32 kg of cast iron per t of steel, the latter showed a much better figure of only 11·09 kg of cast iron per t, thus approaching the normal wastage.—L. H.

A New Type of Feeder Head. I. S. Tkachev. (*Metallurg*, 1957, (5), 30–32). The main disadvantages of hot tops used for the last 20 years at Kuznetsk are difficulties of manufacture, high cost and low mechanical strength. Feeder heads are now all metal lined with fireclay. When filling the mould, after pouring the body of the ingot the pouring stream is reduced to "half stopper" until the level is about 1–½ in. above the lower edge of the hot top. The stopper is then closed for 25–35 sec, enabling the metal entering the gap between mould and feeder head to solidify. The reduced stream is then allowed to fill the hot top to the level required.

Continuous Steel Casting in France. R. Fievet. (*J. Met.*, 1957, **9**, Sept., 1129–1131). The continuous casting plant at the Cail works in Denain, France, includes two twin-strand Junghans machines casting 240 mm sq. bars at speeds up to 575 mm/min. The plant is described, and metallurgical and economic results are discussed. Probable future developments at Cail are considered.

Notes on Continuous Casting in Germany and Belgium. (*J. Met.*, 1957, **9**, Sept., 1132). Brief details are given of: (1) the four-strand Junghans continuous casting machine at the Huckingen plant of Mannesmann-Huttenwerke, used in conjunction with a 35-t electric furnace and casting rounds up to 340 mm dia.; (2) the experimental C.N.R.M. plant at Charleroi, Belgium, which will eventually have four strands with moulds using the B.I.S.R.A. principle.—G. F.

Continuous Casting of Steel. C. Tama. (*Ing. e Indust.*, 1956, **24**, Oct., 105–108). [In Spanish]. Principles of this technique and details of the plant in operation at Atlas Steel Ltd., Ontario, are given. The advantages of this process, and its applications in the Argentine are discussed.

Continuous Casting at Atlas Steels Ltd. L. F. Barnhardt, G. E. Stock, and W. U. Porter. (*J. Met.*, 1957, **9**, Aug., 1050–1051). The authors give a brief description of the continuous casting plant at Atlas Steels Ltd., outlining the design and operation of ladle, tundish, mould, spray cooling, and withdrawal apparatus. The problems of temperature control, refractory selection, and Al addition are considered, and the quality of the product is described.—G. F.

Temperature Recorder Guides Continuous Steel Casting. (*Blast Furn. Steel Plant*, 1957, **45**, July, 739–741). A short review is given of the instrumentation used at the continuous casting plant of Atlas Steels Ltd., in Welland, Ontario.—B. G. B.

PRODUCTION OF FERRO-ALLOYS

Ferrosilicon: Manufacture at Mysore Iron and Steel Works. K. S. Prasad. (*Iron Steel*, 1957, **30**, Sept., 453). The author gives a brief outline of the method of producing ferro-silicon at the Mysore works in India, and indicates how production has been increased by attention to a number of operating variables.—G. F.

The Metallurgy of Ferromanganese. G. Heynert, J. Willems, W. Oelsen, and E. Schürmann. (*Stahl u. Eisen*, 1957, **77**, Nov. 28, 1717–1728). The reactions involved in the reduction of ferromanganese burdens were studied in laboratory trials by melting in crucibles. The relations between manganese, silicon, and carbon and the effects of temperature and of the composition of the slag are discussed by means of a simplified FeO–CaO–SiO_2–Al_2O_3 constitutional diagram. Alloys of high- and low-Si content were produced, good agreement was found between blast-furnace and crucible smelting. The ternary system CaO–MgO–SiO_2–Al_2O_3 is used for discussing the effect of Mg; the regions in which ferromanganese is produced most advantageously are indicated.—T. G.

FOUNDRY PRACTICE

The Foundry Industry in Australia. A. W. Silvester. (*Inst. Brit. Found. Austr.*, 1957, **8**, 1–38). A description with a forecast of future developments is given. Fuel resources are considered and non-ferrous casting is included.

Modern Developments in Foundry Technique. M. Barbero. (*Fonderia Ital.*, 1957, **6**, Sept., 347–354). [In Italian]. The author reviews the latest developments in foundry technique with special reference to the production of motor-car castings. A description is given of modern foundry mechanization, mould and core sand preparation, shell moulding, centrifugal casting and cleaning procedures.—M. D. J. B.

Iron and Steel Castings at the Hannover Fair 1957. W. Schumacher. (*Giesserei*, 1957, **44**, June 20, 361–368). A descriptive and well illustrated article in which exhibits of castings from numerous German firms are described. (27 illustrations).—E. J. W.

Raw Materials for the Foundry at the GIFA. F. Roll. (*Giesserei*, 1957, **44**, May 23, 308–314). A well-illustrated article in which the raw materials and ancillary materials used in all types of foundry are first reviewed. Commercial firms are listed for the supply of melting materials, viz. pig iron, ferrous alloys, and raw material for the light and heavy foundries. Separate sections deal with moulding sands and additions, e.g. quartz sands, bentonites, mould and core auxiliary materials, also heat carriers, electrodes, and refractories.

The Improvement of Cast Iron by Means of Gas Injection. (*Fonderia*, 1957, **6**, April, 149–153). [In Italian]. The effects of O_2, N_2, H_2, and A gas injection into cast irons are described. The resulting mechanical properties and the castability of the irons are discussed.

Calcium Silicide in Ferrous Metal Foundries. (*Fonderia*, 1957, **6**, April, 155–157). [In Italian]. The use of Ca–Si in foundry work is discussed and its advantages over Al as a deoxidizing agent are reviewed.—M. D. J. B.

Studies on Planning in Foundries. R. Sauquet. (*Fond. Belge*, 1957, Nov., 283–285). A summary of the author's paper presented at the 30th Congress of the "Association Technique de Fonderie." Possible errors and pitfalls in planning are discussed and improvements suggested.—E. P.

Preparation of a Moulding Pit. J. J. Harry. (*Inst. Brit. Found. Austr.*, 1957, **8**, 89–92). A design for a pit that can be covered when not in use and the area used for general moulding is shown.

Rational Modernisation in Foundries. A. Plesinger. (*Fond. Belge*, 1957, Nov., 285–289). A summary of the author's paper presented at the 30th Congress of the "Association Technique de Fonderie." Factors affecting productivity are discussed, particularly mechanization.—E. P.

The Foundry in the Age of Automation. P. Schiegries. (*Giesserei*, 1957, **44**, June 6, 337–342). The development of foundry facilities for moulding and melting is reviewed. The pre-requisites for automation in the foundry are then enumerated. Examples and illustrations are given showing the use of automatic equipment in foundries.—E. J. W.

How To Keep a Foundry Automatic. (*Steel*, 1957, **141**, Oct. 14, 120–122). A new automatic foundry for cast iron soil pipe is described. Machinery is hydraulically operated, and is specially designed with standard components for ease of maintenance.—D. L. C. F.

Electromagnetic Lifting Tackle for Foundries. J. Kopeček and J. Prokop. (*Elektrotechnik*, 1957, **12**, (9), 293–294). [In Czech]. An electromagnet weighing 650 lb, with a lifting capacity of up to 3 t, recently developed by the Lenin (Skoda) Works in Pilsen, is described. This type of magnet is intended primarily for lifting castings, while still comparatively hot, from their moulds.—F. F.

The Mechanite Foundry. D. A. Crooks. (*Power-Gas Group Rev.*, 1957, (4), Oct., 2–8).

The Cupola in Foundry Working. (*Fonderia*, 1957, **6**, July, 323–331). [In Italian]. The article describes modern hot blast cupola practice in an up-to-date foundry. Theoretical considerations are discussed and practical results are reported.—M. D. J. B.

Cupola Operation. D. F. O'Connor and C. Morgani. (*Fonderia*, 1957, **6**, Aug., 345–354). [In Italian]. The authors describe cupola practice in some detail and discuss such items as methods of blowing, blast control and charging technique. Technical and operational data are given.—M. D. J. B.

Coke Saving in Cupola Operation. G. Speer. (*Giessereitechn.*, 1957, **3**, Sept., 211). A few practical hints are given. The size of the iron charge, the coke charge, and the amount of O_2 should be balanced empirically one against the other; the iron charge should be of the proper size to suit the cupola furnace; the depth of the coke layer should be between 160 and 180 mm; and the rattler strength of the coke should be at least 82%.—L. J. L.

The Change in Ideas on the Requirements to Be Met by Foundry Coke. C. Gapp. (*Giesserei*, 1957, **44**, June 6, 347–350). The historical development of the requirements to be met by foundry coke are traced from 1894 to the present day, (20 references). Special consideration is given to the reactivity of the coke, the degree of graphitization, and the sulphur and ash contents. Finally, the production of the so-called High Carbon Coke is described and its characteristics discussed.—E. J. W.

Effect of Coke Characteristics on Cast Iron Production in the Cupola Process. A. N. Strykov. (*Liteinoe Proizvodstvo*, 1957, (5), 17–20). The specific characteristics of foundry coke are closely connected with the composition of the charge. The article is a detailed study, theoretical and practical, of the very close connection between the fuel and the finished product.—L. H.

"Slagging of Cupolas." "Jacques." (*Found. Trade J.*, 1957, **103**, Oct. 31, 513–515). An account of usual practice with a description of a slag-hole canopy for discharge to a barrow. Closing the hole using a piece of glass is also described.

Complex Control and Regulation of the Main Processes in Cupola Smelting. N. L. Sobol'. (*Lit. Proizv.*, 1957, (9), 16–18). [In Russian]. Work and operating experience at the "Stankolit" works on the improvement of instrumentation and control of cupolas with recuperator-heating of the blast are described. Controlled parameters are: gas temperature before and after recuperation, cold blast volume and hot blast temperature, CO_2 content of gas. The cold blast volume is automatically adjusted to give a constant mass flow, irrespective of the resistance offered by cupola and recuperator, and can also be automatically increased to allow for lining wear. Remote control of valves has been adopted and experiments with an absorption-type CO_2-analyzer are proceeding.—S. K.

Improvements in the Cupola Process. A New Superheated Cupola for the Production of High Quality Cast Iron. J. Guillamon. (*Fonderie Belge*, 1957, Feb., 15–21). The melting and superheating of cast iron in rotating or coking furnaces, and in normal cupolas with and without fore-hearths is reviewed with particular reference to the processes occurring in the cupola. An account is then given of a method whereby control of the blast enables combustion of the coke to continue in the hearth so raising the temperature of the molten metal. Some results obtained using this technique are briefly described.—B. C. W.

The Model Cupola of the Materials Testing and Research Institute in Brno. B. Sochor. (*Slévárenství*, 1957, **5**, (9), 257–260). [In Czech]. Experiments with a cupola of 6½ in. internal dia., supplied with air preheated to 450° C and having a water-cooled fusion zone, are described. It is shown that this method is suitable for melting grey cast irons of a variety of compositions satisfactorily, the temperature being 1350° C on the average, and 1410° C maximum. The Si and Mn loss is less than in irons made in cupolas using cold air. The air nozzles and intermediate zones have also to be water-cooled to prevent rapid melting and erosion of the lining in these regions.—P. F.

The Operation of Water-Cooled Cupolas. W. J. Ayre. (*Inst. Brit. Found. Austr.*, 1957, **8**, 53–62). The development of cupolas at a spun pipe plant is described, with details of the furnaces and the cooling system.

Superheating of Cold Blast Cupolas. I. Lamoureux. (*Fonderie Belge*, 1957, Feb., 23–26). The development of the cold blast cupola is outlined and methods of raising the tapping temperature of such cupolas are briefly considered.—B. C. W.

Production of Overheated Pig Iron in Hot Blast Cupolas with Bottom Blowing Tuyeres and with Magnesite Linings. F. I. Smirnov. (*Lit. Proizv.*, 1956, (10), 10–13). [In Russian]. A full description of production in a cupola of 3·5-t/h capacity with hot blast between 350 and 400° at 500–550 mm pressure (water column) and 3600 m³/h air is given.—L. H.

Conversion of the Common Cupola into a Recuperative Cupola. (*Fonderia*, 1957, **6**, June, 267). [In Italian]. The article describes the installation of a recuperator in a cupola plant. The conversion resulted in more efficient operation and greater output.—M. D. J. B.

Problems Connected with the Use of Oxygen in the Production of Casting Iron. L. I. Levi. (*Lit. Proizv.*, 1956, **3**, (10), 1–5). [In Russian]. A very detailed study of many aspects connected with this subject such as the optimum consumption of oxygen for obtaining definite temperatures, the method of introducing the gas during treatment of the molten metal, the economics of the process etc., is presented.

The Arc Furnace for Steel Foundries, Its History and Development. L. Arends. (*Elektrowärme*, 1957, **15**, Oct., 345–354). A short history of the arc furnace is followed by an account of the first German Héroult furnace, and modern electrode controls, smoke control during O_2 lancing and induction stirring are reviewed. Refractory linings and electrodes are discussed and the two largest German makers are mentioned.

Induction Melting Furnaces. W. Annen. (*Berg Hütten. Monatsh.*, 1957, **102**, July/Aug., 189–198). The author first discusses the principle of inductive transmission of energy, then deals with the general properties of inductive heat transmission. He then describes, with examples, the various types of induction furnace, and concludes with a brief outline of the metallurgical processes taking place in the induction crucible furnace.

Characteristics and Properties of Cast Irons. (*Tecn. Indust.*, 1957, **36**, July, 807–810). [In Spanish]. A brief account of the structures, properties, and types of ordinary and special cast irons is given.—P. S.

The Classification and Specifications of Cast Irons. A. Secciani. (*Fonderia*, 1957, **6**, July, 295–306). [In Italian]. The author distinguishes between four main groups of cast irons: ordinary, special, low alloy, and high alloy cast irons. The subdivisions in each main group are numerous. These are discussed in some detail. Specifications for these irons are given and testing techniques are discussed.

The Technical and Economic Aspects of the Various Methods of Producing Ordinary Cast Irons. H. Malzacher. (*Fonderia*, 1957, **6**, April, 143–145). [In Italian]. The author describes the operation of the hot blast cupola and the uses of arc and low and high frequency electric furnaces in foundries. Coke quality, furnace charging techniques, temperatures, fluxing materials, slags and alloying elements are briefly discussed.—M. D. J. B.

Recent Developments in the Field of Malleable Castings. K. Roesch. (*Stahl u. Eisen*, 1957, **77**, Nov. 28, 1747–1751). Recent knowledge on melting and heat-treatment of black and white malleable castings resulted in improvements of the properties of the castings. The hot-blast cupola is best suited to the production of white iron, whereas the mains-frequency electric induction furnace produces more satisfactorily black malleable iron. The effect of the S : Mn ratio on temper carbon, graphitizing rate and structure of the matrix of white iron is stressed. Modern heat-treating furnaces using protective atmospheres for black iron are described in detail.—T. G.

Quality Alloy Cast Irons. G. Giacomelli. (*Fonderia Ital.*, 1957, **6**, Sept., 361–366). [In Italian]. The paper reviews the properties of alloying elements and the methods of adding these to the iron. A classification of special alloyed cast irons is suggested which groups these under: high mechanical resistance cast irons, wear-resisting, corrosion-resisting, and heat-resisting cast irons.—M. D. J. B.

Inverse Greyness in White Iron Castings Related to Delayed Cooling at the Surface. G. Östberg. (*J.I.S.I.*, 1958, May, **189**, 57). [This issue].

Formation of Surface Gas Blowholes on Castings of Magnesium Inoculated Cast Iron. A. D. Ushakov. (*Lit. Proizv.*, 1957, (3), 19–20). [In Russian]. A brief report is given of experimental work which has shown that as complete a removal as possible of MgS inclusions from the metal is required to prevent surface blowholes in Mg-inoculated iron castings.

Shrinkage Porosity in Castings. I. B. Kumanin. (*Lit. Proizv.*, 1957, (4), 18–23). [In Russian]. This is a theoretical study of the solidification of castings with special reference to the formation of porosity in tube walls due to shrinkage. Both ferrous and non-ferrous alloys are considered.—S. K.

Checking Production and Controlling Waste. H. Schrader. (*Giesserei*, 1957, **44**, June 6, 350–351). The classification of rejected material in the foundry into main groups, depending on the location at which the faults occurred is described, together with the subdivision of these groups depending on the technical cause of the wastage. The recording of the rejected material by means of card indexes is suggested. Daily and monthly cards are illustrated as examples. The principles of quality control are briefly outlined.—B. J. W.

Comparison of Foundry Productivity. G. de Ghellinck. (*Fond. Belge*, 1957, **10**, Oct., 247–252). The author reviews methods of evaluating productivity in various foundries and advocates even closer co-operation in order to increase foundry output.—R. P.

Estimating Foundry Costs. E. Lotti. (*Fonderia Ital.*, 1957, **6**, Sept., 355–360). [In Italian]. The author describes the methods used in the Fiat foundries for estimating production costs. Much attention is paid to production control and standard costing. Typical progress and costing charts are reproduced.—M. D. J. B.

A Simple Review of Ironfoundry Costing. G. B. Judd. (*Brit. Found.*, 1957, **50**, Oct., 504–513).

Practical Aspects of Abrasive Cleaning in the Foundry. J. F. Attwell. (*Engineer Found.*, 1957, **22**, Sept., 56–61; discussion, 62–63). Sandblasting plant, nozzle type, choice of abrasive, plant installation and auxiliaries, and precautions against silicosis are outlined. The mechanical methods are then considered and vapour and wet blasting referred to.

Safety Measures for Foundry Personnel. (*Fonderia*, 1957, **6**, Aug., 361–369). [In Italian]. The article lists the safety regulations introduced at the Cogne works of 'Nazionale.' Special mention is made of safety measures at blast furnaces and electric furnaces.—M. D. J. B.

VACUUM METALLURGY

Vacuum Metallurgy. (*Prod. Eng.*, 1957, **28**, Mid-Oct., B18–B19). Improvements in 52100 steel and other alloys by vacuum melting are noted among other uses of the process.

Vacuum Melting. (*Wild-Barfield Heat-Treatment J.*, 1957, **6**, June, 2–5). The development of induction furnaces is outlined.

Vacuum Induction Melting-Process Considerations. W. E. Jones. (*Met. Prog.*, 1957, **72**, Oct., 133–138, 220). Purposes, equipment, pumping systems and leak rates, presence of gases, raw materials, and refractories, and the advantages of the process for heat-resisting alloys are discussed.

New Vacuum Melting Furnace at G. L. Willan Ltd. (*Brit. Steel.*, 1957, **23**, Nov., 346–347). A 56-lb. high frequency furnace is briefly described. It is intended for tool and alloy steel melting.

How To Select A Vacuum Arc Furnace. L. L. Johnson. (*Iron Age*, 1957, **180**, Oct. 3, 96–99). Factors which influence the selection of the following five items when specifying vacuum arc melting equipment, are considered: (1) ingot size; (2) electrode size and formation; (3) the vacuum system; (4) the power supply; (5) safety.—D. L. C. P.

Largest Consumable Electrode Vacuum Melting Furnace at Allegheny-Ludlum. (*Ind. Heat.*, 1957, **24**, Sept., 1775–1776). The furnace produces ingots of 26-in. dia. up to 12000 lb weight.

Vacuum Arc Melting Installation of Novel Design at Universal Cyclops. (*Ind. Heat.*, 1957, **24**, Sept., 1786, 1788, 1790). The furnace is primarily intended for Mo and Mo alloys.

Properties of Steel Cast in a Vacuum. V. G. Gruzin and L. L. Gordon. (*Lit. Proizv.*, 1957, **3**, (10), 30–32). [In Russian]. Experiments on various types of standard steels have been carried out. The specimens cast in a vacuum all show a lesser percentage of O_2 and N_2 than the same steels cast under normal factory conditions. The properties of vacuum cast steels resulting from this difference in their chemical composition are set out in detail.—L. H.

REHEATING FURNACES AND SOAKING PITS

Soaking Pits Principles of Design and Operation. G. V. K. Swamy and V. B. Joshi. (*Tisco*, 1957, **4**, Oct., 227–235). The authors outline the characteristics of modern soaking pits and then discuss the role of temperature uniformity requirements and the speed of heating in modern designs. A few typical designs are briefly described together with the latest developments in fast-heating pits. The effect of track time on pit operation is shown, and the importance of proper and uniform charging of pits is mentioned. The external factors which can cause considerable trouble at soaking pits are considered and specific local problems are dealt with.—L. E. W.

Heating Alloy Steel Ingots in Recuperative Soaking Pits. O. A. Semchenko, A. N. Baibuz, N. I. Medvedeva and A. T. Azarov. (*'Stal'*, 1957, (10), 915–917). Temperature drop across the section of ball bearing steel ingots during soaking has been examined and the problem of axial overheating solved. The location of thermocouples and the variations in their readings are shown.—B. S.

Electrically Heated Soaking Pits. W. Poensgen. (*Elektrowärme*, 1957, **15**, Oct., 361–364). Pits heated by troughs of retort carbon are described. Comparison with a blast-furnace gas fired pit is made and the advantage of low rate of scale formation in the ELPITS process is pointed out. The method might be used for other purposes.

Modernisation of the Pusher-Type Soaking-Pit of a Three-High Mill. G. Barth. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1459–1464). The author reports details of the rebuilding of four soaking pits used for heating the stock of a three-high merchant mill. Pulverized-coal firing was replaced by blast-furnace gas, one furnace was completely rebuilt and the others equipped with good heat insulation. A saving of 43% of the calorific energy was obtained, and the pulverized coal saved is now used in the boiler house where it is burnt with a thermal efficiency of 85% against 25% in the soaking pit.—T. G.

Furnace Slides to Work. (*Steel*, 1957, **141**, Sept. 2, 135). Improvements effected in a rolling mill of Republic Steel Corp. are described. A 2000-t billet heating furnace was constructed on an erection site and pushed

100 ft into position, replacing a smaller unit; the loss of production time was 2 months less than it would have been with on-site construction.—D. L. C. P.

Specifications for Non-Electric Metallurgical Furnaces. R. Bureš. (*Hutn. Listy*, 1957, **12**, (10), 883–887). [In Czech]. Standards referring to all types of metallurgical reheating and melting furnaces, excluding steelmaking furnaces proper, are discussed. The relevant Czechoslovak Standard Specifications are listed.—P. F.

Intensification of Working with Air Heaters for Forges and Furnaces. V. A. Kuroedov. (*Vestnik Mashinostroenniya*, 1957, (5), 42–58). This is a study, technical and economic, of the full use of air heating. Conditions for optimum results have been calculated and suggestions made for the intensification of working. Among the latter being an even distribution of gases by a pulsating current, the use of turbulence in the gas stream, supplementary surface heating, etc.—L. H.

Why You Should Use Gas-Fired Furnaces. J. A. Lowe. (*Ind. Gas.*, 1957, **21**, Nov., 12–16). Advantages of using town's gas are discussed for melting, forming, billet heating, and heat treatment.

HEAT TREATMENT AND HEAT-TREATMENT FURNACES

Survey of the Development of the Technology of Heat Treatment of Steels. A. D. Assonov. (*Vestnik Mashinostroenniya*, 1957, (1), 58–64). [In Russian]. After a full investigation of the working conditions in some plants and an examination of the quality of the products, some suggestions for improvement are made, the most important of which are: the liquidation of separate heating sections and forge shops in machine construction plants, so as to ensure isothermal cooling of the forgings; wide use of isothermal hardening and frequent heating both for the hardening and for the chemico-thermal strengthening of the parts in work. The process of surface cyaniding and low temperature tempering must be discontinued and the gaseous process of cementation must be replaced by nitridation.—L. H.

Symposium on the Heat Treatment and Properties of Cast Steels. B. B. Gulyaev and I. I. Goryunov. (*Lit. Proizv.*, 1956, (9), 29–30). [In Russian]. This is a collection of abstracts on this subject published by the Science Institutes in the USSR and by specialists in the subject.—L. H.

Classification of Heat-Treatments by a Numerical Code System. W. Connert. (*Stahl u. Eisen*, 1957, **77**, Oct. 31, 1625–1626). Statistical analysis of heat-treatments can be carried out satisfactorily only if the punched-card system is employed, which requires a numerical code. The author suggests a code system consisting of five figures. Two tables are shown in which the code is explained. The code system does not take times into consideration at present.—T. G.

Modern Heat Treatment Facilities. D. A. Tullock jun. (*Met. Prog.*, 1957, **72**, Nov., 75–78). Hardening of bolts without damage to threads in a new spacious building with good illumination and ventilation is described.

Topical Questions of Metal Science and Thermal Treatment of Cast Iron. A. F. Landa. (*Lit. Proizv.*, 1957, **3**, (10), 13–15). [In Russian]. This is a theoretical study of all aspects based on experiments carried out with specimens containing spheroidal graphite, of the following chemical composition: C 3·0–3·2%; Si 1·8–2·0%; Mn 0·4–0·5%; Ni 0·9–1·0%; P not over 0·09%; Mg 0·08–0·08%; S not over 0·03%.—L. H.

Treatment of Tyre Steels. D. D. Medvedev. (*Stanki i Instrument*, 1955, (10), 26–27). [In Russian]. Experiments with 2 marks of steel are described which were conducted with a view to determining the optimum feed, and quenching treatment in working with these steels to increase productivity. Results of these experiments show a possible increase of between 10 and 14% under working conditions.—L. H.

On Sub-Zero Treatment of High-Speed Steel. M. Kondo. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 62–65). [In Japanese]. Charpy impact values and wear resistance measured on the Skoda machine are reported for 18–4–1 steels after various heat-treatments. Both properties are improved by tempering and sub-zero treatment after quenching in heated oil.—K. E. J.

On Dimensional Changes of Carbon Steel Bars Due to Heating and Cooling. IV. Dimensional Changes Due to the Banded Structure. M. Inagaki. (*Nippon Kinzoku*, 1956, **20**, Feb., 108–112). [In Japanese]. Differential dimensional changes between the longitudinal and transverse directions are analysed in terms of the banded structure for low-carbon, medium-carbon, eutectoid and hypereutectoid steel bars. (11 references).—K. E. J.

The Mechanism of Changes in Shape and Size of Tool Steels by Heat-Treatment. J. Frehser and O. Lowitzer. (*Stahl u. Eisen*, 1957, **77**, Sept. 5, 1221–1233). The studies were carried out on a number of tool steels the composition of which is given. Changes of shape and size as affected by quenching temperature, quenching media and their temperature, tempering, and shape and weight of the samples were studied and the results presented in many graphs and diagrams. The author puts forward a theory as to the mechanisms involved which are used for diminishing the amount of distortion caused by heat-treatment.—T. G.

Walking Beam Furnaces. K. Roney. (*Elect. Rev.*, 1957, **161**, Sept. 6, 403–407). An illustrated account of general heat-treatment installations with details of the mechanism. Power ratings, protective atmospheres and other features are outlined.

Continuous Furnaces with Pusher Conveyors. E. W. Weaver. (*Ing. e Indust.*, 1957, **25**, July, 85–88). [In Spanish]. An illustrated account of the various types of pusher conveyor furnaces for heat-treatment is given. The pusher action, and the various methods of loading, e.g. piece against piece, baskets, trays, vertical suspension etc., are discussed and practical examples are given.—P. S.

Diffusion Chromising of Wood Cutting-Instruments. A. P. Polishchuk. (*Stanki i Instrument*, 1957, (4), 29–30). [In Russian]. A method is described of chromizing by means of a powder mixture consisting of 50% Cr, 45% Al_2O_3 and 5% NH_4Cl, at 1000–1100° C. The thickness of the Cr layer was 10–15 μ.

Technical Review of Some Treatments of Mechanical Parts by Hard Chromising. P. Morisset. (*Métaux–Corrosion–Indust.*, 1957, **32**, May, 208–213). Examples are discussed of hard chromized surfaces. These include the surface treatment of gears, threads, and piston rings to increase their resistance to wear, and of steel parts to increase resistance to salt water corrosion.—B. G. B.

Autogenous Hard-Surfacing of Parts Subjected to Wear, with Particular Reference to Lathe Tools. Grise, Siebel, and Fleck. (*Schweissen*, 1957, **9**, Nov., 473–483). The theory and practice of hard-surfacing is discussed. Hard-surfacing of machine parts increases wear resistance and life of tools. The cutting properties of hard-surfaced lathe tools are better than those of forged high-speed tool steels when working materials of up to 80 kg/mm² tensile strength. Above that, it is advisable to use lower cutting speeds if hard-surfaced lathe steels are employed. (10 references).—R. P.

Use of Beryllium Oxide for the Beryllium Impregnation of Steel. V. A. Parfenov. (*Metallovedenie i Obrabodka Metallov*, 1956, **2**, (3), 17–19). A process for converting BeO to $BeCl_2$ and reacting this with the steel surface is described. Steel with 0·4–0·5% C, 0·45–0·7% Mn, 0·15–0·3% Si, and < 0·3% Cr or Ni was used and test pieces of cylinders 20 mm × 30 mm long with an axial bore 6 mm × 20 mm which was packed with mixture and heated electrically. The best mixture contained 50% BeO, 48% Mg, and 2% NH_4Cl. Depth of impregnation is related to temperature (950–1100° C) and time (0–8 h). Structures are shown.

Five Years' Observations on 'Sulfinuzation.' Y. de Villemeur. (*Métaux–Corrosion–Indust.*, 1957, **32**, June, 249–259). This method is the treatment of steel in a hot bath at 570° C to increase the sulphur content in the surface layers; cyaniding takes place at the same time. Examples of typical metallurgical structures are shown. A number of advantages of the technique are reported. These include: reduced surface friction, absence of deformation during treatment, increased hardness and fatigue resistance, and increased resistance to oxidation and corrosion.—B. G. B.

The Present State of Malleablising Furnaces in Germany. R. Opitz. (*Giesserei*, 1957, **44**, June 6, 342–346). A survey of the conventional and modern malleablizing furnace plants in Germany is first given. Malleablizing times and heat consumption of furnace plants with annealing pots and packing materials as well as of modern plants are discussed. A description is given of furnace plants for white- and black-heart malleable cast irons. Finally, the metallurgical prerequisites for the annealing of black-heart malleable cast iron are set out.—B. J. W.

Why Not Direct Quench? T. W. Ruffle. (*Iron Steel*, 1957, **30**, Sept., 441–444). The author considers the question of hardening case-carburized parts, and suggests that equal and unprejudiced consideration be given to all the alternative methods, including direct quenching. Certain requirements and drawbacks of this particular method are pointed out.—G. F.

Study of Quenching Diagrams of Steels. I. Application of the Oscillograph to Determine the Cooling Rate in Quenching Steels and the Effect of Maximum Heating Temperature on Their Hardenability. T. Sato, K. Mano, S. Toya, and K. Tomabechi. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 177–180). [In Japanese]. The oscillographic technique for recording rapid cooling rates in quenching steels is described. Its use showed that the critical cooling rate is lowest at the eutectoid carbon percentage, that this rate falls with rise of max. heating temp., and that the relationship between critical cooling rate and austenitic grain size is linear for all specimens of carbon steel.—K. E. J.

Controlled Black-Quench. (*Can. Metalw.*, 1957, **20**, Oct., 44). The process enables carbon steels to replace deep-hardening alloy types.

Quench and Temper Process for the Manufacture of High Strength Tubular Products. H. B. Emerick. (*Blast Furn. Steel Plant*, 1957, **45**, June, 608–613; July, 721–726, 738). Recent developments in the American petroleum industry are considered in relation to the use of steel tubing in sinking oil wells. A description is given of a new heat treating process which raises the mechanical properties of ordinary hot rolled tubular products. An illustrated description of the new Jones and Laughlin quench and temper line is given.

Quenching Oil Does Make a Difference. C. Hendra. (*Metalw. Prod.*, 1957, **101**, Nov. 29, 2138–2139). Improvements effected by using a lower viscosity oil of longer life and non-sludging are noted. Both simple hardening and carbonitriding were covered.

Tempering of Hardened Steel. K. E. Johansson and G. Molinder. (*Met. Treating*, 1957, **8**, Sept.-Oct., 16–18, 66, 67). A study of hardening conditions, particularly the time factor, in the tempering of steel strip is reported. The process is explained in general terms and numerous curves are shown. Compositions of 9 steels are given and their tempering properties tabulated. Hardnesses produced are shown.

Manufacture of Steel Springs: Automatic Methods of Heat Treatment. (*Met. Treatment*, 1957, **24**, Nov., 465–467). Methods used by Alco Products Inc. are described.

Stress Relief of Alloy Steels. Commission X Institut International de la Soudure. (*Soud. Techn. Connexes*, 1957, **11**, Sept.-Oct., 333–337). The commission reports on tensile and torsion tests carried out in various countries on specimens heated to various temperatures for various times; the object was to determine the degree of stress relief as a function of time and temperature. Results are given for 13% Cr, 18% Cr–Ni, 0·5% Mo, and some Cr–Mo steels.—B. P.

Cheaper Isothermal Tempering of Wrought Chromium Steel. C. H. Luiten. (*Metalen*, 1957, **12**, Oct. 15, 391–394). [In Dutch]. The author describes the results obtained and the advantages of a method developed in the furnace laboratories of the N. V. Willem Smit Transformatorenfabriek at Nijmegen whereby the usefulness of cutting tools and instruments is improved after forging by subjecting them to a separate isothermal annealing process which interrupts cooling from 700° C for a time.—F. B. H.

FORGING, STAMPING, DRAWING, AND PRESSING

Production of Forgings at the Bromsgrove Works of Garringtons Ltd. (*Met. Treatment*, 1957, **24**, Oct., 401–406; Nov., 459–464). Processes used are outlined and typical products illustrated.

Casting, Forging, Welding and Cutting, Heat Treatment. C. Stieler, O. Kienzle, K. Lange, A. Matting, and W. Stuhlmann. (*V.d.I.Z.*, 1957, **99**, Aug. 21, 1195–1205). Annual surveys of developments are made for each of the above-named processes. The bibliography is in each case fairly comprehensive.—J. G. W.

Radio-frequency Heating in Hot Forging. A Leemann and G. Küchli. (*Microtecnic*, 1957, **11**, (4), 163–169). The importance of short heating times and the effects on microstructure are shown. A hot-forging installation with radio-frequency heating is described.

Proto Tool Company. H. E. Trout jun. (*Steel Proc.*, 1957, **43**, Sept., 493–497). An account is given of the Jamestown Division, Pendleton Tool Industries Inc. The forge and die shops, heat-treating, finishing and handling processes are briefly described.

Automatic Handling Highlights Hammerless Forging Setup. H. Chase. (*Iron Age*, 1957, **180**, Oct. 10, 118–120). The plant described produces crankshaft forgings for Oldsmobile and other car engines. Billets are heated in a rotary hearth furnace, preformed in 2 roll units and delivered to the forging press mechanically. Operators position the work in subsequent operations which involve 2 strikes in a 6000-ton press, trimming, twisting, and positioning. Finally forgings are cooled and heat treated.—D. L. G. P.

The Effect of Forging Ratio on Mechanical Strength of 13% Cr Steel. K. Ono and R. Sasaki. (*Tetsu to Hagane*, 1957, **43**, May, 537–542). [In Japanese]. Forging ratios between 1 and 73 were investigated, and did not affect the tensile strength. Reduction of area and impact value in the longitudinal direction increased up to a forging ratio of 18, then decreased; those at 90° decreased to a ratio of 10·5, then increased. The fatigue strength at room temperature (but not at 500° C) followed the impact value. (10 references).

Mechanization of Gravity Dies. D. Miller. (*Brit. Found.*, 1957, **50**, Oct., 513–516). Replacement of manual labour by mechanical or pneumatic means is described.

On the Origin of the Glassy Surface on Tools in Upsetting. I. V. Trush. (*Vestnik Mashin.*, 1957, (7), 55–56). [In Russian]. During upsetting, the reciprocal interaction of the surface of the articles with the surface of the stamping tools causes sulphiding of the tools. The glassy layer possesses anti-friction properties and low thermal conductivity and has a powerful influence on the strength of the tools.

Stainless Steel Cold Heading Wire. S. E. Tyson. (*Wire Wire Prod.*, 1957, **32**, Oct., 1193–1197, 1248–1250). Types and compositions are given and choice based on corrosion resistance and cold headability is discussed. Mechanical properties are given including work hardening effects. The cold heading operation is outlined and headability parameters are defined. A review of defects is included.

Spin-Forging. A New Machine for the Heavy-Duty Forming of Stainless Steel. (*Aircraft Prod.*, 1957, **19**, Oct., 389). A description of the Hufford machine which handles parts up to 5 ft × 5 ft × 1 in. thick reducing to ½ in. in one pass. One for 10 ft × 10 ft is planned.

A New Hydraulic Extrusion Press for Tubes and Sections. J. Legros. (*V.D.I.Z.*, 1957, **99**, Sept. 1, 1221–1222). A 1600-t extrusion press is described, with the following features: four column press, longitudinally slideable die, overhead guides for container and other ancillary arrangements for the quick, automatic movement of components.—J. G. W.

Extrusion Presses and Press Installations. E. K. L. Haffner and R. M. L. Elkan. (*Met. Rev.*, 1957, **2**, (7), 263–303). Steel extrusion is included.

ROLLING-MILL PRACTICE

Davy-United. (*Steel Rev.*, 1957, Oct., 40–47). An account in general terms of rolling mill construction is given, mainly concerning Velindre.

Expansion Accents Productivity. (*Steel*, 1957, **141**, Oct. 7, 170–173). The extent of the large-capacity units in the mill of the Weirton Steel Co. is described. The latest addition is a continuous cleaning and annealing line that handles 60,000 lb coils of tin plate up to 45 in. wide at up to 2000 ft/min and 60 t/h.—D. L. G. P.

Developments in Rolling Mills. [in the U.S.S.R.]. B. S. Shapiro. (*Stal'*, 1957, (11), 992–996). A review of the last 40 years.

Raising Productivity in Steel Rolling at Effingham Steel Works Ltd. (*Sheet Metal Ind.*, 1957, **34**, Oct., 757–760). Partial mechanization, work study procedures, and organization are outlined.

Jesenice Ironworks and Problems of Rolled Sheet Metal for the Home Market. E. Valentin. (*Nova Proizv.*, 1954, **5**, (3–4), 275–285). Mainly statistical.

The Supply of Rolled Steel Products to Industry in Eastern Germany. H. Schulz. (*Neue Hütte*, 1957, **2**, July, 397–400). The difficulties besetting the supply of rolled steel products to industry in Eastern Germany are attributed not to an insufficiency of the total quantity available, but to the disproportion of those products as regards type, profiles, quality, and size.—L. J. L.

Problems of Boiler Plate Production. M. Gabrovšek. (*Nova Proizv.*, 1954, **5**, (3–4), 249–253). Methods used at Jesenice are considered.

Installations and Operation of A/S Norsk Jernverk. U. Styren. (*Värm. Bergsmänn. Ann.*, 1957, 15–52). The whole works is now in operation and the annual production target of 180,000 t of rolled goods has been reached. Position and planning of works includes information on sources of raw materials, among which is coal from Svalbard. Metallurgical methods and technical details of sinter works, crude iron works, steel works, and rolling mills are given.

Some Examples of Standardisation of Rolling Mill Installations. J. Vaníček. (*Hutn. Listy*, 1957, **12**, (10), 877–880). [In Czech]. Standard designs for two- and three-high mills for the production of billets and sections are given and discussed. Standards for the design of pinion rolls and for individual rolling mill stands are considered. The principles involved in the design of 10 and 30-in. two-high mills for billets and sections are explained, and a table giving roll pressures and torques for the standard designs is given.—P. F.

Analysis of Conditions at any Point between the Rolls with Occurrence of Spread. Z. Wusatowski. (*Arch. Hutn.*, 1956, **1**, (2), 141–169). Formulae previously derived for coefficient of spread and coefficient of elongation during hot rolling of steel give relationships for accurate analysis and for determination of direction of metal flow during spread. Studies in which rolling was interrupted and the upper roll lifted confirmed the calculations with a mean error of ± 1–2%. If the no-slip angle can be obtained the exact velocities of metal entering and leaving the rolls can be calculated from an expression given and also the velocity of flow at any point between the rolls and the amount of slip. The formulae also apply to roll pass design for continuous mills.

Effect of Coefficient of Friction on Spread in Rolling Wedge-Shaped Specimens. W. Leskiewicz and S. Kwiatkowski. (*Arch. Hutn.*, 1957, **2**, (2), 167–182). Studies on rolling have produced contradictory effects owing to the difficulty of investigating flow between the rolls. There is general agreement that deformation in a wedge-shaped die is similar to deformation in rolling and investigations of this process are reported. A relation of coefficient of friction to spread is obtained.

A Width Meter for Narrow Hot-rolled Strip. C. Burns and J. W. Stevens. (*J.I.S.I.*, 1958, May, **189**, 60–65). [This issue].

Calculation of the Pressure on Metals in Rolls during Cold Rolling with Allowance for Tension and Work-Hardening. A. I. Tselikov and A. V. Tret'yakov. (*Vestnik Mashin.*, 1954, (12), 10–12). Equations are derived and curves shown.

Lamination Detector for the Continuous Inspection of Steel Strip. B. O. Smith and A. G. Grimshaw. (*J.I.S.I.*, 1958, May, **189**, 66–71). [This issue].

A Simplified Nomogram for the Determination of the Deformation of Roller Radii in the Cold Rolling of Strip and Sheet. A. Mathea. (*Neue Hütte*, 1957, **2**, July, 417–422). A general survey of previously published nomograms for the determination of the true compressed length in the opening between the rolls is followed by the description of a new and universally applicable nomogram for the determination of elastic deformation of the rolls based on the Hitchcock equation.—L. J. L.

Non-Slip Angle and Forward Slip during Rolling with Spread. Z. Wusatowski and Z. Szalajda. (*Arch. Hutn.*, 1957, **2**, (2), 127–166). A relation between the two parameters is found and a nomogram is given for its solution. Many rolling tests are described and a relationship to spread is worked out.

Internal Stresses in Hot-Rolling Rolls Induced by Service-Stress. H. Bühler. (*Stahl u. Eisen*, 1957, **77**, Nov. 28, 1740–1747). The author describes the methods used for the inspection of four hot-rolling rolls after long service. He found that zones which were highly stressed during normal service are characterized by tensile stress in the surface. The factors, including vibrations, responsible for the origin of these stresses are discussed. Compressive stresses in the surface of the rolls were found at zones where small or no stresses occurred during normal rolling.—T. G.

Mathematical Study of the Effect of Rolling Speed on Rolling Force and Strip Thickness in Cold Rolling. W. Lueg and P. Funke jun. (*Stahl u. Eisen*, 1957, **77**, Oct. 3, 1356–1362). The theory of Sims and Arthur (*J.I.S.I.*, 1952, **172**, 285) is explained and discussed. L. and F. present a number of diagrams for $\mu = 0{\cdot}05$ and $0{\cdot}08$ (μ = friction coeff.) and find good agreement between calculated and measured forces and strip thickness.—T. G.

The Position of the Neutral Angle in Hot and Cold Rolling Processes. Z. Wusatowski. (*Arch. Hutn.*, 1955, **3**, (1), 11–42). Formulae previously advanced are brought to a common form or shown to yield the same values. Cases of homogeneous and inhomogeneous compression with sliding friction are considered and conditions for obtaining the neutral angle defined. Hot rolling with spreading is treated, and comparisons with practical trials are made. Conclusions are given.

The Wear of Rolls on Continuous Sheet Mills. E. M. Palamarchuk. (*Stal'*, 1957, (10), 929–933). Careful observation of working and supporting rolls is necessary and in shaping the working rolls the wear of the supporting rolls should be allowed for.

Forces Acting in Blooming Mills. E. S. Rohotyan. (*Vestnik Mashin.*, 1955, (1), 25–29). [In Russian]. The article presents a mathematical investigation of the forces acting in rolling mills such as those exercised by the metals on the rolls, the torsion moments etc. and from them are deduced the parameters of the rolls and instruments. The theoretical part is well documented with findings from experiments.—L. H.

The Application, Production, and Heat Treatment of Cast Alloy Steel Rollers. H. Uhlitzsch and G. Radomski. (*Neue Hütte*, 1957, **2**, Nov., 655–664). This, the first of a series of articles, deals with the stresses that occur in cast steel rolls during heat treatment, and how they can be calculated. Equations are derived for heat

and transformation stresses in the heat treatment of solid cylinders, and formulae are given for the calculation of surface- and core temperature, the maximum temperature gradient between core and surface, their equilibrium temperature, and temperature distribution over the cross-section of solid cylinders. An example is given to illustrate the practical application of the formulæ.—L. J. L.

Transport Equipment for Coils in Wire-Rod and Thin-Section Mills. G. Leder. (*Stahl u. Eisen*, 1957, **77**, Sept. 5, 1244–1246). The design and layout of conveyors for the transport of coils weighing 100–500 kg each are discussed. One of the main difficulties encountered is that the coils must be cooled below 550° C before they can be transported by the hooks of the conveyor as above this temperature they tend to lose their shape.

MACHINERY FOR IRON AND STEEL PLANT

First Results Obtained with Electronic Weighing Devices in an Iron and Steel Works. H. Knüppel, G. Wiethoff, and W. Dörr. (*Stahl u. Eisen*, 1957, **77**, Nov. 28, 1752–1759). The Baldwin-Honeywell weighing system using electric strain gauges is described and results obtained in an iron and steel works are given.

Power Plants for Iron and Steel Works. E. A. Dzhaparidze. (*Stal'*, 1957, (11), 1017–1023). A review of the last 40 years with statistics.

Development of Power at the Jesenice Ironworks. D. Sikosek. (*Nova Proizv.*, 1954, **5**, (3–4), 264–271). Electric, gas, and water-power installations are all noted.

Development of Works Internal Rail Transport Systems. S. S. Berlyand. (*Stal'*, 1957, (11), 1028–1031).

Marshalling in the Works Yard and Its Control by Light Signals. H. Bergrath. (*Stahl u. Eisen*, 1957, **77**, Oct. 31, 1611–1613). A modern light signal system is described.—T. G.

LUBRICATION

Failure of a Set of Roller Bearings. C. G. McDonald, A. L. Temby, M. E. Hargreaves, and A. J. W. Moore. (*Wear*, 1957, **1**, Aug., 64–70). Steel rollers in bronze cages failed on change of lubricant, but were found to have been soft on installation. The first lubricant was found to have bound and the second to have released the flakes already formed.

Functional Testing of Cold Reduction Lubricants. J. F. Griffin. (*J. Met.*, 1957, **9**, Aug., 1042–1043). The author describes certain tests which have been devised to evaluate the frictional properties of rolling oils under extreme pressures at speeds approaching zero. By means of these tests, the lubricating properties of oils and their effects on cooling and on the cleaning and annealing characteristics can be measured, eliminating the need for costly mill trials.—G. F.

Tests on Rolling Oils and Rolling Oil Emulsions in Cold Rolling. I.—Rolling with Lubricants Consisting of Pure Base Oils and Additions. W. Lueg, P. Funke, jun., and W. Dahl. (*Stahl u. Eisen*, 1957, **77**, Dec. 12, 1817–1830). The authors tested 34 lubricants from natural greases ranging through mineral oils to fatty acids and emulsions. Rolling force, torque, and forward slip as well as friction were measured. They found, *inter alia*, that it is not the quality of free fatty acid that is the important factor, but the structure of the base lubricant. Additions of free fatty acid give an improvement only if the base lubricant is already a good one, particularly if its viscosity is lowered by the fatty-acid addition.—T. G.

Tests on Cold-Rolling Oils. P. Funke jun. (*Stahl u. Eisen*, 1957, **77**, Dec. 12, 1836–1838). A review of published information, mainly of German origin.—T. G.

Experiments on the Friction and Endurance of Various Surface Treatments Lubricated with Molybdenum Disulphide. A. A. Milne. (*Wear*, 1957, **1**, Oct., 92–103). Mild steel rings were run in contact until seizure occurred. Untreated, phosphated, and sulphided surfaces with four MoS_2 formulations were tested.

WELDING AND FLAME CUTTING

Technology of Welding. T. Artynov. (*Ing. e Indust.*, 1956, **24**, Oct., 109–113; Nov., 112–118). [In Spanish]. Modern methods and techniques of welding are reviewed. In the first part, fusion and resistance welding applications are described and illustrated. In the second part, arc welding procedure is discussed at length.—P. S.

Shielded Inert-Gas Metal-Arc Welding. D. B. Tait. (*Brit. Weld. J.*, 1957, **4**, Nov., 501–513). A consumable bare wire electrode is used with $A + O_2$ mixture for ferrous materials. Characteristics of the arc are shown and costs of welds in 18–8 stainless and mild steels are tabulated in detail.

Arc Welding Shielded with Inert Gas. L. Wolf. (*Jernindustri*, 1957, **28**, Nov., 218–224). The article was originally written for the 5th International Congress for the Engineering Industries. General advantages of the method, cleansing effect of the arc, importance of compensated alternating current, technique, apparatus, economic comparison of different processes and the technical importance of the method with alloys are discussed by the author.

The Effects of Impurities in Argon on Inert-Gas Shielded-Arc Welds. D. C. Moore and C. A. Terry. (*Brit. Weld. J.*, 1957, **4**, Nov., 511–513). R. A. Creswell. (513). Correspondence on the paper in the same Journal, April, 1956, 181–188.

The Sigma Welding of Mild Steel. D. B. Tait and J. S. Owen. (*Engineer Found.*, 1957, **22**, Sept., 41–46). Shielded Inert Gas Metal Arc welding is described and discussed. A water-cooled gun with self-adjusting arc and wire feed is used. CO_2 can be used. Magnetic flux gas-shielded arc welding is also considered.

Welding of Cast Iron. H. Beyer. (*Giesserei*, 1957, **44**, June 20, 374–382). The relevant properties of cast iron are considered in relation to its weldability. Some cast irons can be welded, others not. The stress conditions, welding rods and the various methods of welding cast iron are then discussed. This latter includes hot, warm, and cold welding techniques. The texture and strength of hot- and cold-welded cast irons are described and compared. The economics of welding cast iron are briefly considered.—B. J. W.

Welding Cast Iron Leads to Considerable Saving in Costs in Metallurgical Industry. C. Elster. (*Varilna Tehn.*, 1957, **6**, (2), 96–97; from *Klepzig Fachberichte*, 1957, June). (A translation from German).

Problems of Welding High-Tensile Structural Steels. H.-J. Wiester. (*Schweissen*, 1957, **9**, Oct., 465–468). An increase in the N_2 content up to 0·03% and formation of AlN in finely divided form improves the structure and mechanical properties of structural steels. The normalized steel has a yield limit of 44–50 kg/mm² and tensile strength of 60–67 kg/mm². These steels are not sensitive to brittle fracture and can be welded easily. The influence of up to at least 0·1% P on the brittle fracture is annulled by the fine grain due to nitrides. (18 references).—B. P.

Welding Stainless Steels. R. E. Paret. (*Machinery*, 1957, **91**, Nov. 8, 1095–1102). Austenitic, ferritic, and martensitic types are reviewed and oxy-acetylene, arc, and resistance welding methods discussed.

Welding of Stainless Steels with Fusible Electrodes in a Current of Argon. J. Němec. (*Zvárania*, 1957, **6**, (11), 337–342). An account of the Aircomat process is given.

Some Metallurgical Aspects of Welding Stainless Steel. F. A. Ball and J. Hinde. (*J.S.A. Inst. Min. Met.*, 1957, **58**, Sept., 83–96). The relationship of welding properties to the amount of austenite, martensite, and ferrite and consequently to alloy composition, as well as the effects of Si and N, and theories of hot-cracking are discussed. The welding of the hardenable steels and of FV520 is also reviewed.

Welding in an Argon Atmosphere with a Consumable Electrode. A. Baron. (*Rev. Gen. Mec.*, 1957, **41**, July-Aug., 302–306). A description is given of this technique and of the results obtained. It has been satisfactorily used with Al alloys, Cu, and stainless type steels.—B. C. B.

Brazing Alloy Selector. (*Steel*, 1957, **141**, Oct. 7, 162–165). More than 400 alloys for brazing ferrous and non-ferrous metals are listed. Properties and applications are given in the text, American trade names, compositions and melting ranges in the tables.

Gas-Cutting in Modern Production Works. H. Christoph. (*Schweissen*, 1957, **9**, Oct., 441–447). The author discusses the physico-chemical principles of flame cutting. He then considers the influence of design of the cutting machine, control of head, nozzle shape, and fuel gas on the cutting accuracy. Various types of controlling mechanisms are described. Cutting accuracy depends on the dimensions of the product.—B. P.

How To Make Oxygen Cutting Do More Jobs. C. Underwood. (*Iron Age*, 1957, **180**, Aug. 29, 63–66). The range of applications of torch cutting is indicated, and the conditions for efficient work are considered.—D. L. C. P.

Cutting Low-Alloy Steels With Oxygen. R. Rohan. (*Zvárania*, 1957, **6**, (9), 258–265). [In Czech]. The technology of the process is discussed in detail, and the metallurgical aspects of cutting typical Cr–Mo steels is used as an example for illustrating the general metallurgical principles and problems of the method.—P. P.

Instruments PP-1 and PP-2 for Oxygen Cutting of Steels. (*Stanki i Instrument*, 1955, (7), 37). [In Russian.] These are respectively single and double cutting instruments for low-carbon sheet steels of from 5 to 100 mm thickness. They can be used for straight cuts, for circular cuts with diameters up to 540 mm and for irregular curves, and have wide limits of speed ranging between 70 and 1500 mm/min.—L. R.

MACHINING AND MACHINABILITY

Relative Cost and Machinability of Carbon Steels and Alloy Steels. D. Mascio. (*Prod. Eng.*, 1957, **28**, Mid-Oct., 1321–1323). Tabulated data are given showing properties, machinability, and uses.

Sub-zero Machining and Quenching. R. J. Delaney. (*Machinery*, 1957, **91**, Sept. 6, 548–551). Quenching at — 40° F (from + 40° F) maintains the "as quenched" ductile state in alloy steel and other metals and eliminates breakage in forming operations. Cr–Mo steel sawing and machining are facilitated.

High Speed Cutting of Reclaiming Steels. M. S. Polyak. (*Stanki i Instrument*, 1957, (1), 30–31). [In Russian]. It is advisable to increase the C and V content in alloys simultaneously. For every 1% increase in V there is a corresponding increase in C of 0·16–0·17%, but a C increase lowers the plasticity of the steels. The important factor in estimating the resistance to wear of these alloys is the suitability of the shape of the instruments and the distribution of the carbide phase.—L. H.

The Influence of Structure on the Machinability of Structural Steels. W. Knorr. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23**, Aug., 258–266). The influence of structure and composition on the machinability of low-carbon and case-hardening steels is discussed. A pearlite-ferrite structure is desirable. Maximum machinability of Mn–Cr and Mo-case hardening steels is obtained when the grain size is 2 to 3 ASTM units. Mo and S improve machinability. Isothermal transformation is recommended for alloyed structural steels. High austenizing temperatures increase the pearlite/ferrite ratio. Heat-treatment of these steels should be carried out by referring to *TTT* curves. (11 references).—B. P.

Thermal Deformation of Tools in the Cutting of Cast Iron. L. G. Kuklin. (*Vestnik Mashinostroenniya*, 1957, (3), 46–48). [In Russian]. The experiments were carried out in the laboratory of the Leningrad Institute with clean turned cast iron with cutting plates of 4 mm thickness of the hard alloy steel BK8 on the lathe and on the boring tool, the sections having an area of 16 × 16 mm². The specimens were subjected to variations of conditions such as, cutting speeds, temperature, depth of cut, etc. and, in conclusion, mathematical

equations have been obtained from the observed data for the relation between the thermal linear expansion and the depth of the cut, and between that expansion and the hardness of the cast iron.—L. H.

Machinability of the Steel 40XHBA in Turning and in Drilling. P. A. Markelov. (*Vestnik Mashinostroenniya*, 1957, (2), 54–55). [In Russian]. This is a Cr–Ni–W steel and its machinability for cutting and drilling is tabulated.—L. H.

Heat Balance in Cutting Titanium Alloy BT 2. A. M. Danielyan. (*Vestnik Mashinostroenniya*, 1957, (1), 39–43). [In Russian]. The heat balance, and in particular the quantity of heat which passes into the shavings, the cutter, and the workpiece depend essentially on the quality of the metal. The average data obtained which characterize the thermal balance of turned steels, cast iron and Ti alloy BT 2, with a speed of 10–50 m/min, are tabulated. Upon investigating the appearance of elevated temperatures in working Ti alloys, with a view to raising the stability of the tools, it became evident that the use of cooling fluids must be assured during working.—L. H.

Metallographic Study of Chip Formation During Cutting. M. Weiss. (*Pub. Inst. Rech. Sid.*, 1957, Series **A**, No. 142, Feb., 204 pp.). A comprehensive review of factors influencing the formation of chips during cutting is presented. The theory of their formation is first reviewed. Methods of studying the problem are next considered. The mechanism of the formation of chips for a number of materials having different crystalline structures is discussed. The deformation and friction occurring during cutting are examined, particular reference being made to mild and alloy steels. Reference is made to the influence of the conditions of cutting on chip formation and to the improvement in ease of cutting by the presence of sulphur in mild steels. The results obtained are given in full in a series of appendixes.—B. G. B.

Influence of the Machined Diameter on the Behaviour of Cutting Tools During the Turning Operation. F. Eugène, B. Juque, and R. Parran. (*Microtecnic*, 1957, **11**, (4), 147–150). The tool wear is greater when the piece is of small diameter as it is related to the time between consecutive passes and this is less with the smaller piece.

Tool Wear in Machining as Shown by Tool-Wear/Cutting Speed Curves. G. Vieregge. (*Stahl u. Eisen*, 1957, **77**, Sept. 5, 1233–1244). This is a very thorough investigation on tool wear showing, *inter alia*, the following result: In the machining of cast iron by cemented carbides, particularly those having a high-Co content, the carbon of the cast iron tends to diffuse into the tool tip thus loosening the binding of the cemented carbide. This effect is more pronounced in TiC than in WC–Co alloys. In the machining of steel, the steel tends to extract carbon from the tool tip at cutting temperatures of 800° C and higher and to form mixed carbides of the type $(W, Fe)_6C$. TiC, TaC, and TiC–TaC–WC are less prone to mixed iron carbide formation than pure WC–Co tips.—T. G.

Effect of Manganese and Lead on the Machinability of Rimming, Free-Cutting Steel. H. Becker and H. Hoff. (*Stahl u. Eisen*, 1957, **77**, Sept. 5, 1215–1220). The authors carried out machinability tests using hard-metal bits on a number of basic-Bessemer steels of various Mn and Pb contents. The results obtained are presented in tables, diagrams, and micrographs, the latter showing the effect of inclusions on machinability. Sulphide segregations improved machinability, and times between regrinding of the tips increased with Mn content. Lead showed no general improvement in machinability; it is, however, useful in cases where a thin layer is removed at low cutting speeds.—T. G.

The Use of Cooling–Lubricating Fluids for the Grinding of Hard- and of Alloy Steels. M. A. Askarov. (*Stanki i Instrument*, 1957, (1), 31–33). [In Russian]. The experiments were arranged for varying conditions; with cooling, without cooling, with combined cooling and emulsions and with combined cooling, emulsion and the addition of 1% oleic acid. Two types of steel were investigated with cutting speeds of between 128 and 223 m/min. Full details of the findings are given.—L. H.

New Theory Bolsters Grinding Research. P. M. Unterweiser. (*Iron Age*, 1957, **180**, Sept. 12, 127–129). The work of Prof. Kenjii Sato in elucidating grinding conditions is explained. Mathematical treatment is supported by heat measurements during grinding operations. Of the total heat generated during the grinding of a medium carbon steel, about 84% entered the workpiece, 4% the chips, and 12% the wheel. The ratio of remaining heat to the total heat entering the workpiece increases with wheel depth of cut and with decreasing table feed; it is thus desirable in finish grinding to use a shallow grind and a high table speed.—D. L. C. P.

The Grinding Wheel, an Expensive Tool. E. Fuchs. (*Giesserei*, 1957, **44**, June 6, 354–356). The difficulties encountered in the determination of the most economic grinding wheel are discussed. The costs are related to the hardness of the wheel. The problems found in controlling the quality of grinding wheels are described, these include the effect of binding materials and the pressure applied. Suggestions are made on how these problems may be solved; a simple testing device is illustrated.

De Laval Turbomatic Centrifuge for the Clarification of Grinding Coolant. (*Machinery*, 1957, **91**, Sept. 27, 769–771).

A Method of Handling Swarf and Recoverable Metals. L. J. Hoefkens. (*Mech. Handling*, 1957, **44**, Dec., 686–693). Design of containers for swarf handling, emptying, oil separation, sorting and crushing and the economics of the process and wage bonus incentives are discussed.

CLEANING AND PICKLING

Recommended Practices for Cleaning Prior to Electroplating. S. Spring. (*Amer. Soc. Test. Mat., S.T.P.*, 197, 1957, 37–48). A list of surface soils and methods and mechanisms for their removal are given.

Experience Gained in the Use of Mechanical Descaling Plants for Steel Rod and Semi-Finished Products. F. Schweitzer. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1476–1482). The author describes the various types of mechanical descaling plant and discusses quality, uniformity, and price of a number of types of grit. The results obtained in descaling bars and rods were satisfactory independent of the type of plant and grit. Efficiency and costs depend on the use of the correct type of grit.

Mechanical Descaling of Wire by Shot Blasting. E. Jaenichen, A. Duphorn, H. Krautmacher, and W. Püngel. (*Stahl u. Eisen*, 1957, **77**, Dec. 12, 1785–1795). A "Wheelabrator" shot-blasting plant for the mechanical descaling of wire is described. Basic converter, O.H., and 0·77% C steel wire was descaled. Further operations after descaling were carried out as usual and used to compare the behaviour of the wires with wires descaled by bending and pickling. The surface quality of the shot-blasted wire is intermediate between those treated by the two other methods, lubricant consumption is highest with shot-blasted wire. Costs of shot-blasting are about 20% higher than for pickling.—T. G.

Special Application of Oxy-acetylene Flame De-scaling to the Preparation of Rolling Mill Products for Spot Welding. M. Evrard. (*Soud. Techn. Connexes*, 1957, **11**, Sept.-Oct., 297–317). This paper shows that the presence of scale on the surface of rolling mill products impedes the application of resistance spot welding. Such products can be treated by heating with an oxy-acetylene flame, followed by immediate water cooling; this eliminates scale and provides suitable surface conditions. (16 references).—B. P.

The Technical Value of Shot Blasting. (*Usine Nouv.*, 1957, **13**, Nov. 28, 94). A review of the process and its advantages over sand-blasting is given. Compressed air and mechanical methods are briefly noted and shot peening is referred to. The kinds of shot used are named.

Chemical Cleaning of the Inside Surfaces of Apparatus and Fittings in Industry. F. Podbrežnik. (*Zaštita Mat.*, 1954, **2**, Apr., 113–115). The use of chemical agents and inhibitors is reviewed.

A Contribution to the Study of Electrolytic De-rusting of Steel Samples. F. Podbrežnik, O. Pavlovic, and M. Blažon. (*Zaštita Mat.*, 1954, **2**, Feb., 39–41). Laboratory studies in 5% H_2SO_4 with 2-naphthol, 10% ammonium citrate solution, and 8% caustic soda are described. Ammonium citrate was the best agent for cathodic derusting without removal of metal.

On the Mechanism of the Process of the Electrochemical Polishing of Metals. S. Ya. Grilikhes and N. P. Fedot'ev. (*Zhur. Prikl. Khim.*, 1957, **30**, (4), 528–533). [In Russian]. The authors suggest that two processes must be distinguished in electrochemical polishing: the removal of micro-unevennesses from the surface and the growth of its reflecting power. They produce experimental evidence to support this.—S. K.

Etching Stainless Steel by the Electrolytic Method. W. E. McFee. (*Products Fin.*, 1957, **21**, July, 42–43). The principle and an outline of the practice of the Armco Research Laboratories process are given.

Experimentation with Scale Models to Study the Continuous Electrolytic Treatment of the Surface of Sheet Steel. L. Ferrand. (*Mém. Soc. Ing. Civils France*, 1957, **110**, Mar.-Apr., 85–108). A short discussion on the use of scale models is first presented and it is shown how these models can be used in the study of electrolysis in aqueous solutions. The problems studied include the continuous pickling of sheet steel and Ni, Cr, and Zn plating. The results obtained are compared with those obtained on the full scale plant and show the good agreement between the two. The application of the results obtained with models to the design of new plant for Ni, Cr, and Zn plating are discussed with examples.—B. G. B.

Dependence of Anodic Potential of Steel on the Composition of the Electrolyte in Electrochemical Polishing. N. P. Fedot'ev and S. Ya. Grilikhes. (*Zhur. Prikl. Khim.*, 1957, **30**, (2), 233–239). [In Russian]. The results of an experimental study of the influence of temperature, CrO_3 concentration, presence of iron salts and water content on the electrolytic polishing of steel are presented. Type St. 45 carbon steel formed the anode, curves of current density against anode potential under the various conditions being obtained. In one experiment on the CrO_3 effect a chrome steel was used as the anode, the results showing that Cr takes part in the formation of the anode film. The film is formed only in an electrolyte of definite composition and under definite electrolysis conditions.—S. K.

Selecting Mechanical Finishes for Stainless Steel. R. E. Paret. (*Mat. Design Eng.*, 1957, **46**, Sept., 110–114). Mirror, satin, and textured finishes are considered. Mill finishes are tabulated and further treatments outlined.

Barrel Finishing. A. S. Kohler. (*Metal Finishing*, 1957, **55**, Aug., 58–64; Sept., 59–63; Oct., 68–73). A general review is given of the process, nomenclature, and tumbling barrel design, construction and lining, auxiliary equipment, and tumbling media with a survey of abrasives are included. Deburring processes are then reviewed, and finally the effects of shape on barrel action, barrel loads, and a review of methods, abrasives, and times for parts of steel forgings, stampings, and hardened parts and non-ferrous materials is given.

The Role of Modern Barrel Finishing. C. J. Glasrud. (*Plating*, 1957, **44**, Jan., 47–51). An account of an interview.

Barrel Finishing Made Simpler. P. Kaftol. (*Steel*, 1957, **141**, Sept. 9, 108–109). A table is given which specifies the tumbling media and compound to be used, and the water level, for the various types of barrel finishing operation.—D. L. C. P.

Preparation for Electroplating with Coated Abrasives. W. K. Seward. (*Plating*, 1957, **44**, Jan., 43–46). Contact wheels, working pressures, belt speed, abrasive selection, handling and storage, and lubricants are reviewed.

How to Select and Use Contact Wheels. W. K. Seward. (*Products Fin.*, 1957, **21**, July, 24–35). Contact wheels for abrasive belt

polishing are discussed, and design, dressing, operating speed, belt tension, abrasive size and characteristics, and effects on ferrous and other metals are reviewed.

Fused Salt Pickling of 1H13 Steel. E. Gasior. (*Prace Inst. Miniet. Hutnic.*, 1957, **9**, (2), 61–69). Pickling in acids and the advantages of fused salts are described. The scale formed on steel with 0·12% C and 12·64% Cr during annealing at 900° is examined and the presence of chrome spinel resistant to acids is shown. With NaOH–$NaNO_3$ at 500° Cr_2O_3 is removed and Fe_3O_4 converted to Fe_2O_3, quenching in water removes most of the remaining deposits.

Exhaust Ventilation with Pickling Tanks. H. Allen. (*Metalw. Prod.*, 1957, **101**, Nov. 1, 1964). A general discussion.

One System Handles Many Wastes. (*Steel*, 1957, **141**, Sept. 16, 146–152). The system for handling waste water at 1600 gal/min from a large Buick car plant is described. The wastes consist of spray booth residues, pickle acids, chrome liquors, cleaning machine effluent, soluble and insoluble oils. Oily wastes are collected in a holding basin, skimmed and dredged, and chemically treated. (Waste pickle liquor is used to break the water soluble oils). The clarified water can be re-used. Reclaimed oil is sold or burned.—D. L. C. F.

Survey of Disposal and Recovery of Spent Pickling Liquids. K. Mathesius. (*Stahl u. Eisen*, 1957, **77**, Oct. 3, 1349–1355). The author reviews the various methods for recovery and neutralization of H_2SO_4 in pickling plants with special reference to the precipitation of $FeSO_4.7H_2O$.—T. G.

PROTECTIVE COATINGS

Metal Casting Research at the Skotty Hall Laboratories of BISRA. (*Met. Fin. J.*, 1957, **3**, July, 273–280). A general review of the work of the laboratories with notes on the structure of coatings on iron single crystals, X-ray thickness measurement, Al and other electrodeposits, Fe–Zn alloys and Fe–Sn alloy deposits, identification of differentially coated electrolytic tinplate, anodizing of Al-coated steel, vapour phase and electrophoretic coatings, Plasteel and its properties, strip lacquering, and hot metal coating practice, is given.

Present State of Electrodeposition. W. Machu. (*Stahl u. Eisen*, 1957, **77**, Oct. 3, 1374–1383). A review of published information with 77 references and a bibliography.—T. G.

Plating and Surface Finishing Facilities for a Machine Shop. C. C. Clayton. (*Products Fin.*, 1957, **21**, Aug., 36–41). An account of cleaning, liquid honing, chrome plating, and nickel deposition in the machine shops of Douglas Aircraft is given. Liquid honing of stainless steel is referred to.

Electrochemical Deposition of Metals. S. Vučkovic. (*Zaštita Mat.*, 1954, **2**, May-June, 137–141). A general review.

Influence of Organic Substances on the Kinetics of the Cathodic Process and Hydrogenation of Iron Coatings. Yu. N. Petrov. (*Zhur. Prikl. Khim.*, 1957, **30**, (5), 729–735). [In Russian]. In connection with the increasing use of electrolytically deposited iron for the building-up of worn machine parts the author has studied the influence of glycerol, dextrin, sucrose, gelatin and citric acid on the kinetics of the process and hydrogen pick-up by the iron. The direct compensation polarization-curve method was used, temperature control being to ± 0·2° C. A porous-glass diaphragm separated the cathode from the anode liquids. A 15 × 15 × 1 mm iron plate served as the cathode. Polarization curves obtained under various conditions are presented and discussed.—S. K.

The Role of Hydrogen in the Process of Metal Electrodeposition. K. M. Gorbunova. (*Proc. Electrochemical Conference 1955, Warsaw*, 1957, 483-497). **Heterogeneity in Electrode Surfaces and the Process of Metal Electrodeposition.** A. T. Vagramyan. (499–514).

Protecting Metals with Inert Barriers. (*Prod. Eng.*, 1957, **28**, Mid.-Oct., C2–C5). Corrosion processes are indicated and organic, metallic and vitreous coatings briefly reviewed.

Methods of Determining the Quality of Galvanic Coatings. M. B. Pajevic. (*Zaštita Mat.*, 1954, **2**, Oct., 243–247). Detailed accounts of physico-chemical and exposure methods are given.

Evaluation of Methods Available for Measurement of Surface Lustre of Electroplated Coatings. G. B. Bowman. (*Amer. Soc. Test. Mat., S.T.P.* 197, 1957, 25–36). Electroplated decorative coatings are tested by Surface Analyzer Tapes and by optical methods and various instruments were compared. No instrument was suitable for all the surfaces examined.

Some Testing Cells for the Study of Electroplating Devices. J. K. Skwirzynski and M. Huttly. (*J. Electrochem. Soc.*, 1957, **104**, Nov., 650–656). A trapezoidal and a triangular cell are described with nearly linear current density distribution. Mathematical analyses are given and the characteristics shown graphically.

The Inspection of Electrodeposits. N. A. Tope. (*Insp. Eng.*, 1957, **21**, July-Aug., 74–79; Sept.-Oct., 102–108, 101). An introduction on the general properties of electrodeposited metals and bright coatings is followed by an account of thickness tests and throwing power and the use of specifications. The strip and weigh method is described, also time of gassing tests, the BNF jet test, microscopical and non-destructive methods, porosity tests and factors leading to coating porosity, adhesion and adhesion testing, lustre, and specifications, with notes on anodizing and phosphating and their examination.

Plating Shop Floors that Resist Corrosion. E. G. Rawlings. (*Ind. Fin.*, 1957, **9**, July, 699–701). A review of requirements and of the 6 groups of corrosion-resisting mortars is given, with sections on design, drainage, and resistance to HF.

Recent Trends in Plating Power Supplies. J. E. Mungenast. (*Products Fin.*, 1957, **21**, July, 72–74). A review, with brief mentions of rectifiers, magnetic amplifiers, and controls.

Compressed Air and Its Application to Metal Finishing. J. Robertson. (*Electrepl. Met. Fin.*, 1957, **10**, Nov., 366–370, 373; Dec., 397–399, 401–402). Typical installations are described and the use of air agitation in plating solutions is outlined.

Electrolytic Hardening. Immersion Method—I. S. Owaku and K. Kuroyanagi. (*Nippon Kinzoku*, 1956, **20**, Feb., 63–67). [In Japanese]. For electrolytic hardening of steel, electrolytes of salts (e.g. Na_2CO_3, K_2CO_3) showed good results. The optimum concentrations of HCl and Na_2CO_3 were 2% and 10%, respectively. The higher the temperature of the electrolyte, the lower the voltage needed to heat the specimen. At 210 volts, variation of the distance between specimen and anode in the range 10–100 mm did not affect the c.d.

Chromium Electroplates. (*Mat. Design Eng.*, 1957, **46**, Sept., 151, 153). A collection of data on types of plating, mechanical properties, pre-treatment, bath compositions, deposit thickness, and finishing is presented.

Automatic Plating Plant. (*Auto. Eng.*, 1957, **47**, Sept., 361–364). Two mechanized lines for Cu, Ni, and Cr plating at Fiat Mirafiori Works are illustrated and described.

The Chromium Plating of Gun Barrels. R. A. F. Hammond. (*Bull. Inst. Met. Fin.*, 1957, **7**, Spring, 83–110).

Testing of a Barrel Chromium Plating Machine Manufactured by Riedel Co. and the Use of Chromium Plating Baths Containing Sodium Fluorosilicate. T. Hayashi, T. Ito, and S. Takagi. (*Rep. Gov. Ind. Res. Inst.*, 1957, **6**, Apr., 207–210). Maker's recommendations are given but it was found that sulphate ion did not need to be reduced below 0·5 g/l., poor plating resulted with > 10 g/l. chromic ion, plating speed was 0·05–0·1 μ/10 min. and the sodium salt of H_2SiF_6 could be used.

Stop Chrome Waste, Pollution and Heat Loss. E. W. Neben. (*Plating*, 1957, **44**, Jan., 52–55). A plating solution recovery system is described. Acid is recovered by evaporation and a heat-exchange system is incorporated.

The Economics of Treatment of Strong Chromic Acid Solutions. G. E. Glover. (*Plating*, 1957, **44**, Feb., 161–165). A comparison of the costs of destruction and recovery is made. The problem is one of removing accumulated impurities and exchange resin methods are considered. From the figures given recovery, with or without dilution and reconcentration, is usually the better method.

Electron Microscope Studies of Copper Electrodes in Sulphate and Cyanide Baths. S. Okada and S. Magari. (*Tech. Rep. Eng. Res. Inst. Kyoto Univ.*, 1957, **7**, Mar., 17–48).

Electrolytic Copper Plating from an Ammoniacal Electrolyte with the Aim of Local Protection of the Surface of Steel Parts during Case Hardening. N. A. Marchenko. (*Zhur. Prikl. Khim.*, 1957, **30**, (2), 248–255). [In Russian]. It has been shown that an electrolyte containing 90–80 g/l. of $CuSO_4.5H_2O$, 15–20 g/l. of $NiSO_4.7H_2O$, 80 g/l. of $(NH_4)_2SO_4$, 80 g/l. of $Na_2SO_4.10H_2O$, and 180 ml/l. of 25% ammonia can be used to give local protection of steel surfaces by electrolytic deposition of copper.—S. K.

Sprayed Molybdenum and Its Applications. S. M. Wright. (*Alloy Met. Rev.*, 1957, **8**, Sept., 2–8). Hard facing and other uses are reviewed. Techniques are surveyed and observations on adhesion reported.

Cermets as High Temperature Protective Coatings. (*Ceramics*, 1957, **9**, Aug., 29–31). Use of a Ni–MgO cermet is described which is flame-sprayed on a sand-blasted surface. Ti nitride cermets are then reviewed with details of tests made and properties developed by the coated materials and the cermets.

The Linde Flame-Plating Process. H. J. Haycock and R. J. Fraser. (*Machinery*, 1957, **91**, Sept. 27, 738–742). Wear-resisting surfaces are produced by flame spraying of WC or Al_2O_3. The surface is not usually raised above 400° though the flame attains 6000° F and the particles travel at 9000 ft/sec. Preparation and finishing and the uses of parts are described.

On the Oxide Layers of Iron and Aluminium. A. Köniser. (*Giesserei*, 1957, **44**, Aug. 1, 457–461). The influence of the casting or annealing skin (oxide layer) on the mechanism of corrosion is discussed. Gases are reputed to be the cause of swelling in the oxide layer. The influence of local rust formation at the surface on blow-hole formation is discussed: the manner in which this is reduced, by annealing in an inert atmosphere, is described. The conditions necessary for the formation of a dense oxide skin are enumerated. Corrosion behaviour of cast iron is compared with that of Al.—R. J. W.

Modern Installations for Phosphating. (*Tecn. Indust.*, 1957, **36**, Aug., 968–970). [In Spanish]. A brief review of the principles and techniques of the phosphating process as an industrial operation is given.—F. S.

Coatings for Anticorrosive Protection in Water. Koloomb. (*Zaštita Mat.*, 1954, **2**, Feb., 42–45). Bituminous, polyurethane, polyvinyl, and chlorinated rubber coatings are reviewed.

Rubber Coatings as Protection from Corrosion. V. Velic. (*Zaštita Mat.*, 1955, **3**, Jan., 19–20).

Epoxy-Fibreglass Armouring for Corrosion-Erosion Protection. W. F. Oxford jun. (*Corrosion*, 1957, **13**, Oct., 615). Uses in oil fields are shown.

A Practical Method of Determining the Thickness of Oily Layers of Non-Mineral Origin on Tin, Iron, and Other Metal Surfaces. J. J. Trillat and B. Schreiber. (*Chim. Ind.*, 1957, **78**, Nov., 476–479). A preferential staining method for colorimetric use is described.

Investigations on the Phenomena Occurring During the Enamelling of Cast Iron. D. Kamran. (*Giesserei*, 1957, **44**, Nov. 21, 705–713). The structure of the scale is discussed, followed by considerations of the oxidation rate of cast iron in various gases and of enamelled iron. The surface conditions of shot-blast plate and castings are compared. A study is made of the effect of elements added, superheating of the melt, wall thickness, moisture, and of the adhesive power of the enamel on spheroidal graphite cast iron and on white cast irons.—R. P.

Action of Enamel Melts on Steel. G. I. Belyaev. (*Zhur. Prikl. Khim.*, 1957, **30**, (7), 1077–1080). [In Russian]. The corrosion of steel in fused electrolytes has been investigated with reference to enamelling practice. The steel was low-carbon sheet. Intense solution

of iron with gas evolution was observed in fused silicate and borate glasses and enamels. The rate of corrosion depended on the chemical composition and basicity of the melt: there was more corrosion in sodium silicates than in sodium borates, and corrosion increased with increasing N_2O and decreasing B_2O_3 and SiO_2 contents. In borate-free base enamels the steel was oxidized more strongly than in borate-enamel melts. The solution is considered to be an electrochemical process with evolution of hydrogen and oxides of carbon.—S. K.

Barrel Enamelling. W. S. Field. (*Bull. Inst. Met. Fin.*, 1957, **7**, Spring, 111–113). Treatment of small parts is referred to, and the factors concerned in the process are enumerated.

The Development of Vitreous Enamel as a Building Material in the U.S.A. E. Mackarek. (*Met. Fin. J.*, 1957, **3**, July, 295–298).

Wire and Strip Continuously Annealed and Enamelled in Universal Ovens. (*Ind. Heat.*, 1957, **24**, Sept., 1838, 1840). A new design by General Electric is briefly outlined.

A Survey of Paint Application Methods. IV. Dipping Methods; Flow Coating. E. A. Blount. (*Products Fin.*, 1957, **21**, Aug., 24–35).

Water-Thinned Paints for Metal Products. (*Mat. Design Eng.*, 1957, **46**, Oct., 137–139). A group of styrene–butadiene copolymer latex formulations is described.

POWDER METALLURGY

Powder Metallurgy. J. F. C. Morden. (*Metal Ind.*, 1956, **89**, Oct. 19, 329–332; Nov. 16, 409–411; Nov. 23, 435–436; **90**, Jan. 11, 23–25; Feb. 8, 103–105, 108; Apr. 5, 265–268). Methods of production of metal powders are reviewed and mechanical, reduced, and electrolytic powders compared. Methods of mixing and forming are then considered and effects of oxide impurities. Dies and presses are reviewed and methods of compacting. Furnaces and furnace atmospheres are described with a table of their uses. Growth and shrinkage are then discussed and porosity control and theories of sintering.

Recent Developments in Powder Metallurgy. I. Jenkins. (*J.I.S.I.*, 1958, May, **189**, 15–18). [This issue].

Ten Years of Powder Metallurgy in Italy. N. Corsini. (*Met. Ital.*, 1957, **40**, Aug., 557–560). [In Italian, with English translation]. A brief chronological review is given of developments in powder metallurgy in Italy over the last ten years. Reference is made to the leading metallurgists who pioneered this field and to their work.—M. D. J. B.

Developments in the Production and Quality of Metal Powders. (*Report of Discussion of the Powder Metallurgy Joint Group of the I.S.I. and Inst. Met.*, Dec., 1957, *Advance Copies*).

Recent Developments in Powder Metallurgy. I. Jenkins. (*No preprint available*). The inaugural lecture for the group.

Atomisation of Metal and Alloy Powders. J. F. Watkinson. (Pp. 7). Production of stainless steel and other powders by dispersion of molten metal by water or air jets is described. The problem of surface oxidation is discussed and the size distribution of the powders produced. Atmosphere control can be used, though subsequent reduction in hydrogen has been employed. The plant now developed is outlined.

Electrolytic Production of Straight and Alloyed Metal Powders. F. Ljungberg. (Pp. 7). Iron powder production in acid aqueous solutions, fused salts, alkaline solutions, and amalgams are outlined. Ferro-alloys are similarly produced using either alloy anodes, soluble anodes of each metal, insoluble anodes with continuous addition of salts or combinations of these methods. Fe–Ni and Fe–Mo powder production are described, with the fused salt method for Cr alloys.

Electrolytic Copper Powder. E. Mehl. (Pp. 7). The theory is outlined and compared with practical results.

Mechanical Methods as Used in the Carbide Industry. E. M. Trent. (Pp. 6). Milling processes are described.

Production of Powders of Some of the Reactive Metals. G. L. Miller. (Pp. 10). Be, Zn, Ti, Ta, Nb powder production by reduction and electrolytic methods are discussed.

The Manufacture and Properties of Metal Powders Produced by the Gaseous Reduction of Aqueous Solutions. J. P. Warner. (Pp. 13). The production of Co, Ni, and Cu powders by direct or indirect reduction with hydrogen is reviewed. Screen analyses are shown.

The Techniques of Pressed Metal Powders. H. Silbereisen. (*Met. Ital.*, 1957, **40**, Aug., 561–567). [In Italian, with German translation]. The paper reviews methods of pressing sintered powders and discusses the scope of the technique. Details are given of press designs, the choice of steel, the preparation of powders, and the methods of compensating for shrinkage.—M. D. J. B.

Some Practical Experience of Sintering Metals under High Vacuum. M. Mamula. (*Neue Hütte*, 1957, **2**, Aug., 497–502). The description of a vacuum bell for the sintering of metals by direct application of electric current and of a vacuum furnace for sintering and annealing is followed by an account of experience gained in the installation and operation of the equipment.—L. J. L.

New Problems Encountered in Powder Metallurgy. E. M. Onitsch-Modl. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23**, July, 209–215). The author discusses the developments in powder metallurgy over the last ten years. Included are improvements in mass production of small sintered parts and in the process for rolling endless strip from metal powders. This is followed by a discussion on high-temperature materials, theoretical considerations, and studies regarding the reactions in the solid state.—E. P.

Furnace Sintering of Metals and Ceramics. R. L. Harper. (*Metal Progress*, 1957, **72**, Aug., 69–72). A short general review of this subject is presented. Iron, stainless steel, magnetic materials, and carbides are considered.

Furnaces for Sintering and Heat Treating Powder Metal Parts. N. K. Koebel. (*Metal Progress*, 1957, **72**, Aug., 65–68). A short description of mesh belt, roller hearth, and mechanical pusher type furnaces is given. The batch-type vertical radiant tube furnace is considered particularly suited for hardening sintered iron and steel parts in controlled atmospheres.—B. G. B.

Physical and Mechanical Properties of Sintered Parts. M. Eudier and B. Hocheid. (*Met. Ital.*, 1957, **40**, Aug., 573–580). [In Italian, with French translation]. Theoretical generalities on sintered metals are briefly discussed and a detailed review is made of their mechanical and physical properties: modulus of elasticity, tensile strength, hardness, capacity to absorb vibrations, coefficient of expansion, conduction, and magnetic properties. Considerable technical data in table and graph form are given.—M. D. J. B.

Extreme Precision is Possible. N. H. Sanderson. (*Prec. Met. Mold.*, 1957, **15**, Nov., 42). Sintered parts of powdered iron are reviewed as used for instrument parts. The higher costs of precision parts is noted.

Slip Casting. A New Method in Powder Metallurgy. H. H. Hausner. (*Met. Ital.*, 1957, **40**, Aug., 626–636). [In Italian, with English translation]. Slip casting is described. The method consists in preparing a fluid suspension of metal powders, pouring these into a plaster of Paris mould, expelling and firing the partially dried casting in a sintering furnace. The advantages of the method are discussed as well as the range of applicability. Examples are given.—M. D. J. B.

Problems of Powder Metallurgy in the Production of Machine- and Instrument-Parts. F. Eisenkolb. (*Neue Hütte*, 1957, **2**, Aug., 461–470). Metal powder production is surveyed; industrial applications are listed; methods of producing iron-, non-ferrous-, and light metal powders are described; testing, preparation for pressing, metal powders for production of sintered steel and sinter alloys, and the manufacture of superfine powders and powders with special particle shapes are discussed.—L. J. L.

Sintered Iron-Base Alloys for Machine Parts (II). Properties of Sintered Iron Made by the Re-Pressing Method. E. Hayashi, G. Matsumura, T. Watanabe, and Y. Fujii. (*Rep. Gov. Ind. Res. Inst.*, 1957, **6**, Mar., 143–149). Both reduced and electrolytic powders were used. The density is greatly increased by a second pressing and, according to the pressure used, may rise 5–22%. Dimensional shrinkage by subsequent pressing is small. The number of pores is much reduced and grain growth seems to be promoted. The mechanical properties improve as the pressure is increased, electrolytic powder gives better elongation and impact strength than reduced powder.

Note on the Application of Powder Metallurgy to Munitions Manufacture. A. Bia. (*Met. Ital.*, 1957, **40**, Aug., 568–572). [In Italian, with English translation]. The author shows (i) how powder metallurgy makes it technically and economically possible to mass produce parts otherwise difficult to manufacture, and (ii) how powders can be substituted for materials which are in short supply. To illustrate this the author describes in some details the manufacture of shell bands made from sintered iron powders instead of the conventional copper.

Controlled Atmospheres in Powder Metallurgy. I. Montevecchi. (*Met. Ital.*, 1957, **40**, Aug., 587–597). [In Italian, with English translation]. Reducing atmospheres are used in sintering processes to avoid chemical alteration of the green compacts and to reduce the oxides which might be found in the process. The uses of hydrogen, ammonia, exothermic, and endothermic gases and special atmospheres are described and their relative merits are reviewed.—M. D. J. B.

Effect of Porosity on the Properties of Sintered Powder Permanent Magnets. A. B. Al'tman. (*Fiz. Met.*, 1957, **4**, (1), 84–88).

On the Magnetic Properties of Reduced Metal Powders. H. Kojima. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 74–77). [In Japanese]. Oxides of Fe, Ni, Co, and Fe–Co prepared from the oxalates, formates, and carbonyls were reduced in H_2, compacted and tested. The most suitable reducing temperatures for each compound were determined. Iron showed the highest coercive force and nickel the lowest. To obtain high coercive forces, fine, acicular oxide powder is indicated as starting material. (14 references).—K. E. J.

Molybdenum Elements in Electric Furnaces for Sintering Metals. O. Dorigo. (*Met. Ital.*, 1957, **40**, Aug., 598–604). [In Italian, with English translation]. The heat resisting properties of Mo (melting point 2600° C) for use in the manufacture of electric furnace elements are discussed. Three types of sintering furnaces are described in some detail: the normal pressure furnace, the protective atmosphere furnace, and the vacuum furnace. Automatic temperature control is also discussed.—M. D. J. B.

FERRITES, CERMETS, AND CARBIDES

Synthesis of Some Ferrites. H. Kedesdy and A. Tauber. (*Trans. Amer. Inst. Min. Met. Eng.*, 1957, **209**; *J. Met.*, 1957, **9**, Sept., 1140–1148). Ferrites are sintered metallic oxides of the general formula $MeFe_2O_4$. The authors discuss the results of systematic investigations of the formation of a basic ferrite, such as Ni-ferrite; a mixed ferrite, such as NiZn-ferrite; and a ferrite involving a complex formation process, such as Mn-ferrite. Specimen preparation and testing procedures are described, and trends in magnetic characteristics are related to changes in firing cycle and furnace atmosphere.—G. F.

Some Factors Involved in the Preparation of a Reproducible Magnesium–Manganese Ferrite. L. C. F. Blackman. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Nov., 624–635).

Manganese–Zinc Ferrite with High Permeability and Low Loss. W. Heister. (*Tech. Mitt. Krupp*, 1957, **15**, Nov., 130–144).

Electrical Properties of Some Single Crystals and Polycrystalline Ferrites. V. A. Ioffe, G. I. Khvostenko, and Z. N. Zonn. (*Zhur. Tekn. Fiz.*, 1957, **27**, (9), 1985–1995).

Ceramic Cutting Tools. Application to Production Jobs. J. F. Allen. (*Can. Metalw.*, 1957, **20**, Oct., 24, 26; Nov., 26–28). Experience with ceramic tips is outlined and the use of a tip protector described. So far it has not been possible to use them in the first roughing cut.

Cermets. C. A. Bertella. (*Met. Ital.*, 1957, **40**, Aug., 637–646). [In Italian, with English translation]. The author gives a chronological review of the development of cermets and lists the names of the main pioneers in this field with brief reference to their work. High temperature ovens for research on cermets are described as well as methods of testing these materials. Testing techniques examined include creep tests, thermal shock tests, corrosion, thermal expansion and micrographic tests, and practical application tests. An account is given of the present stage of research on cermets.—M. D. J. B.

Cermets: III, Modes of Fracture and Slip in Cemented Carbides. N. M. Parikh. (*J. Am. Ceram. Soc.*, 1957, **40**, Oct., 335–339).

Progress in Cermets and Their Recent Industrial Applications. (*Génie Civil*, 1957, **134**, Sept. 15, 379–381). Use in the machining of iron and steel is reviewed.

Possibility of Obtaining Cermets on the Basis of Borides of Chromium, Titanium and Tungsten. I. I. Iskol'dskiĭ and L. P. Bogorodskaya. (*Zhur. Priklad. Khim.*, 1957, **30**, (2), 177–185). [In Russian]. It was found impossible to produce cermets based on chromium, titanium, and tungsten borides with cobalt, nickel, and iron as cementing metals since these react with the borides. The further investigation of this effect is urged.—S. K.

The Substitution of Iron–Nickel Binders for Cobalt in Cemented Carbides. R. Kohlermann and R. Wehner. (*Technik*, 1957, **12**, Nov., 736–740). Comparative tests have shown that Fe–Ni can be substituted for Co, even in carbides with a high binder content, without affecting quality.—L. J. L.

Method of Investigating the Equilibria in the Formation of Carbides from Oxides at High Temperatures. V. S. Kutsev, B. F. Ormont, V. A. Epel'baum, and L. Ya. Karpov. (*Zhur. Fiz. Khim.*, 1955, **29**, (4), 629–634). A vacuum furnace arrangement for measurements of equilibria is described and changes of CO pressure are measured and chemical and X-ray studies carried out on the reaction products. A study on the ZrO_2–C system is reported.

Recent Progress in Hard-Metal Engineering in the East German Republic. C. Agte. (*Neue Hütte*, 1957, **2**, Sept., 537–544). Research has recently been carried out in Eastern Germany with the object of effecting economies in imported raw materials. Results are described concerning reductions in cobalt requirements and the substitution of TiC for WC. A comparison is made between the newly developed hard metals and multi-purpose metals and the conventional hard metals. Production methods can be rendered more economical by the use of vacuum sintering.—L. J. L.

PROPERTIES AND TESTS

Conference on the Activity of Research Laboratories in Industry. Work Carried out by the Research Laboratories of the Electro-Chemical, Electro-Metallurgical and Electric Steel Making Societies. R. Perrin. (*Ind. Nat.*, 1957, (3), 75–82). The speaker gave a summary of the work carried out by the Society; this includes laboratory and pilot plant tests on steels, ferro-alloys, powder metallurgy, and chemistry.—B. P.

The Physics and Chemistry of Metals. N. F. Mott. (*Year Book of the Physical Society*, 1957, 1–13). The nature of the metallic bond and the form of the Fermi surface is discussed. Effects of mechanical properties are outlined and stacking fault energies and the energy of activation of cross-slip for dislocations considered.

Design Principles for Metal Properties. C. Zener. (*Prod. Eng.*, 1957, **28**, Mid-Oct., B2–B5). Atomic structure is described in general terms as a guide to alloy formulation.

The Results of Forty Years' Work on Mechanical Testing in the U.S.S.R. N. N. Davidenkov. (*Zavods. Lab.*, 1957, **23**, (10), 1245–1265). A review, 1917–1957, with 274 references.

Testing and Measurement of Engineering Surfaces. A. Wiemer and R. Lehmann. (*Technik*, 1957, **12**, July, 477–483). The geometrical aspects of engineering surfaces are considered in a general survey, comprising definitions of roughness and established methods of measurements.—J. G. W.

Furnaces and Temperature Controls for Physico-chemical Studies up to 1700° C. G. Urbain and G. Cavalier. (*Sil. Indust.*, 1957, **22**, Oct., 527–532). Carbon tube and Mowound furnaces and their regulators are reviewed.

Standards for Surface Irregularities. (*Prod. Eng.*, 1957, **28**, Mid-Oct., A25–A27). Values for various types of finish are recommended and methods of measurement briefly reviewed.

Acceptance Testing of Materials and Products. R. Schinn. (*Stahl u. Eisen*, 1957, **77**, Nov. 14, 1674–1686). The author discusses the merits of the various types of destructive and non-destructive testing and stresses the difficulty of a correct interpretation of the test results by quoting a number of examples.—T. G.

Developments in Metal Defectoscopy. S. T. Nazarov. (*Zavods. Lab.*, 1957, **23**, (10), 1230–1234). A review, 1917–1957.

Calculations of the Thermodynamic Constants of Metallurgical Processes. Reactions in the Liquid Phase of Iron. A. Krupkowski. (*Arch. Hutn.*, 1953, **1**, (2), 107–129). [In Polish, with English and Russian summaries]. The free energy changes for the equilibria between α and liquid iron, FeO solid and liquid, the $Fe + \frac{1}{2}O_2 \rightarrow FeO$ liquid reaction and the liquid $Fe + H_2O$ reaction are calculated. A series of FeS reactions is also evaluated from the Gibbs–Dubem equation over the range 1260–1810° K. The Fe–FeO liquid system is also considered and a value for the heat of solution of FeO in liquid iron obtained. (~ 18500 cal/mole).

Rails Made from L.D. Steel. H. Laitzner. (*Zeitschrift des Oesterreichischen Stahlbauvereines*, 1957, **3**, (2), 29–31; Translation T.S. 706). Mechanical properties are considered in relation to probable length of service and their acceptance under standard specifications. Tensile, impact, and wear-resistance values are measured.

A Simple Laboratory Method for Determining Modulus of Elasticity. B. E. Vassiliou and C. J. W. Baker. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, Oct., 499–508). Apparatus for measuring deflection under load of centrally loaded (refractory and ceramic) bars is described.

Variation of Elastic Constants of Hardened 1 per cent Carbon Steels on Tempering. A. F. C. Brown, A. G. Cole, and M. F. Markham. (*Nature*, 1957, **180**, Dec. 7, 1254). Ultrasonic measurements are reported on steels quenched in oil from 780° and tempered 1 h between 100–650° C in steps of 50°. The static values are about 1% lower than ultrasonic values for rigidity modulus for tempering up to 450° and negligibly different at higher temperatures.

On the Elastic After-effect in Carbon Steels. A. V. Bryukhanov. (*Doklady Akad. Nauk S.S.S.R.*, 1957, **113**, (5), 1046–1049). Low-carbon and eutectoid steels of different grain size were subjected to tensile tests. It was found that the elastic after-effect depends on (1) time of loading, (2) structure of samples. The results are discussed and two formulæ are given.—S. I. T.

The Mallock Cone Hardness Test and its Relation to Indentation Methods. G. H. H. Williams and H. O'Neill. (*J.I.S.I.*, 1958, May, **189**, 29-37 [This issue].

Flow and Fracture. E. R. Parker. (*Met. Prog.*, 1957, **72**, Nov., 65–69). A general account of solid state physics in relation to design and the properties of materials.

A Theory of the Fracture of Metals. A. N. Stroh. (*Advan. Phys.*, 1957, **6**, Oct., 418–465). Transcrystalline fracture of polycrystalline materials is considered beginning with the strength of ideal lattices and Griffith's theory. Brittle fracture is reviewed in terms of piled up dislocation groups and crack growth and hydrogen embrittlement, slip, the lower yield point, brittle–ductile transition, crack propagation, ductile fracture, and stress effects are formulated with appendices on crack energy and initial growth. (83 references).

A New Concept of Hydrogen Embrittlement in Steel. J. G. Morlet, H. H. Johnson, and A. R. Troiano. (*J.I.S.I.*, 1958, May, **189**, 37–44). [This issue].

The Electrical Resistivity of High-purity Iron–Carbon Alloys. S. V. Radcliffe and E. C. Rollason. (*J.I.S.I.*, 1958, May, **189**, 45–48). [This issue].

On the Mechanism of the Effect of Boron on Hardenability. I. H. Imai. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 106–110). [In Japanese]. The adsorption of boron and other interstitial solute elements in the quenched state was followed by etching the steel with aq. $NaOH$–$NaNO_3$ solution. Boron atoms adsorbed on a grain surface fill up the lattice defects or diffusion vacancies, thus reducing internal strains; the effect is to reduce the instability of austenite grain boundaries and to suppress the transformations beginning there.—K. H. J.

Steels and Tool Bits Modified with Boron. (*Prod. Eng.*, 1957, **28**, Mid-Oct., B15–B17). Types 302 and 316 stainless and low-C steels are improved by addition of B or of B and Ti. Cutting tests and 100-h rupture strength results are given.

Influence of Silicon, Nickel, Carbon and Chromium on the Properties of Valve Steel Containing 20% Chromium. N. Yamanaka and K. Kusaka. (*Tetsu to Hagane*, 1957, **43**, May, 550–556). [In Japanese]. The effects of these elements were examined on a 20% Cr valve steel, used because of its high resistance to attack by the products of combustion of leaded petrols. Results are given for the changes in critical point, hardenability, amount of retained austenite, and tensile strength.

Activities of Manganese and Carbon in Fe–C–Mn Melts. M. Ohtani. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9A**, Oct., 426–433). An expression for solubility of C in Fe–Mn melts is given, up to 40% Mn at 1530° ± 10° C. Activities in the range up to C saturation over the same range of Mn content at 1540° C were measured using a concentration cell.

On the Activities of Si and C in Molten Fe–Si–C Alloys. M. Ohtani. (*Nippon Kinzoku*, 1956, **20**, Feb., 96–100). [In Japanese]. Measurements on a slag conductivity cell provide values for the activities of silicon in Fe–Si and Fe–Si–C alloys, and for the interaction coefficients of C and Si. (10 references).

A Weldable, Hardenable 12% Chromium Alloy. W. R. Kegerise. (*Wire Wire Prod.*, 1957, **32**, Oct., 1224–1226, 1258–1260). The alloy developed contains 0·035% C, 0·50% Mn, 0·30% Si, 11·7% Cr, 1·5% Ni, and 0·02% N. Tests simulating welding conditions were carried out and hardness, tensile, and impact tests were measured. Welding tests of various kinds were then made.

Tool Steels, VI: Steels for Plastic Moulding Applications. L. F. Spencer. (*Steel Proc.*, 1957, **43**, Oct., 570–575). Typical compositions are given and selection is discussed. Heat treatment, temper, hob steels, chromium plating, and similar subjects are considered and forging practices tabulated.

Studies on the Industrialisation of the "MT" Permanent Magnet. I. On the Chemical Composition and Additional Elements. T. Mishima and N. Makino. (*Tetsu to Hagane*, 1957, **43**, May, 556–560). [In Japanese]. "MT" alloy is a ternary Fe–Al–C alloy developed to replace Alnico etc. in war-time. It is shown that the optimum magnetic properties are developed in the composition ranges 8·0 ± 0·2% Al, 2·0 ± 0·1% C, and this is confirmed from the phase diagram. Additions of Cu, Sn or Ni improve the magnetic properties, but not when in amounts exceeding 3%.—K. H. J.

The Use of Common Structural Steels. W. Küntscher. (*Technik*, 1957, **12**, Aug., 555–559). Following a general discussion of the main features of structural steel and problems arising in welding, recommendations as to choice for particular applications are made with reference to specifications of SAE high-strength aircraft steels, of German Lloyd plate steel for shipbuilding, and a proposed DNA list. In general the point is made that for a plate thickness below approx. ½ in., rimming steels are entirely adequate.—J. G. W.

Precipitation Hardening Stainless Steels. Firth-Vickers Ltd. (*Met. Treatment*, 1957, **24**,

Nov., 437–438). Properties of F.V. 520 steel are described. The steel is machinable and weldable and is resistant to high temperatures.

British and American Standard Steels. W. B. Kemmish. (*Mat. Design Eng.*, 1957, **46**, Oct., 171, 173, 175, 177; Nov., 167, 169, 171). Tables comparing standards are given.

The Development of Heat-resistant Metals and Methods of Testing them in Czechoslovakia. J. Pluhar. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 707–710). Work has in recent years been done, in Czechoslovakia, on ferritic and austenitic heat-resistant steels for tubes, forged and cast components, bolts, and turbine blades at temperatures up to 700° C. The object is to replace Ni and Mo by V and W or Mn without detriment to the high-temperature characteristics of the steels.—L. J. L.

Studies on the Mechanical Properties, Workability and Heat Treatment of Ti–Fe–Al Alloy. H. Kusamichi, Y. Yagi, T. Yukawa, H. Toda, and K. Miyamoto. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 81–85). [In Japanese]. By double melting, a sound ingot of titanium containing about 2% each of Fe and Al was produced. The alloy showed satisfactory high-tensile properties, and was easily hot-forged and rolled; the tensile strength is 90 kg/mm² at room temp., and 130 and 150 kg/mm² after 50% and 80% reduction, respectively. Details are given of other properties at various temperatures, and the structure after various heat-treatments.

Some Experiments on High-Carbon and High-Vanadium High-Speed Steel. H. Kaneko. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 59–62). [In Japanese]. Laboratory tests are reported on heat-treatment, hot-hardness, impact properties, and cutting power of high-C high-V steels. Since the matrix carbon is lower and complex carbides higher than normal, these steels are easy to forge and heat-treat. The best properties for tools, especially fine drills, are found with a composition of 1·4% C, 5–10% W, 4% Cr, and 5·5% V.

Study on Heat-resisting Steel. X. E. Asano. (*Tetsu to Hagane*, 1957, **43**, May, 543–550). [In Japanese]. Results are given for the effects of B and Ti, separately and together, on the properties of Timken 16–25–6 after solution treatment at 1150–1200° C and ageing at 700°, 750°, 800°, and 850° C.—K. E. J.

Metallurgical Research in Australia. H. K. Worner. (*J. Austral. I.M.*, 1957, **2**, Aug., 1–12). A lecture reviewing research facilities.

Standardisation in the Design Practice for Metallurgical Laboratories. J. Pekárek. (*Hutn. Listy*, 1957, **12**, (10), 887–891). [In Czech]. The Standard Specification HN 43 9110, developed by the State Planning Office for Metallurgical Projects, for the design of works laboratories is discussed.—P. F.

METALLOGRAPHY

Progress and Trends in the Development of Soviet Metallography. M. L. Bernshtein, M. E. Blanter, and M. G. Lozinskii. (*Zavods. Lab.*, 1957, **23**, (10), 1202–1211). A review, 1917–1957.

A Criterion for the Existence of an Intermetallic Compound in a Binary System. A. Krupkowski. (*Arch. Hutn.*, 1956, **1**, (1), 3–9). Mathematical.

Orientation Determination of Crystal Grains by Light Figures. M. Yamamoto and J. Watanabe. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9A**, Oct., 410–418).

Orientation Determination of Cubic Crystal Plates by the Light-Figure Method. M. Yamamoto and J. Watanabe. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9A**, Oct., 395–409). Iron and 3% Si–Fe were studied.

High-Temperature Microscopy. P. Rys. (*Neue Hütte*, 1957, **2**, Aug., 489–497). Groove formation at the austenite grain limit, graphite layers, and deformation of polished surfaces are discussed. Studies were carried out with the high-temperature microscope built by L. Bezdek and D. Ruzicka which incorporates a vacuum furnace in which the sample is either heated direct by electricity or by heat transfer.

Impregnation of Porous Minerals for Microscopical Studies. J. Cloth. (*Stahl u. Eisen*, 1957, **77**, Nov. 14, 1691–1692). The author describes a method of impregnation of porous materials in which a self-setting synthetic resin is pressed into the pores of the sample by hydraulic pressure. Setting, accelerated by the addition of a catalyst is complete under pressure in 2–3 hours.—T. G.

Baker Interference Microscope for Inspecting Surface Finish. (*Machinery*, 1957, **91**, Nov. 22, 1196–1198).

Elucidation of Metal Microstructure with the Ultra-violet Microscope. T. G. Porokhova. (*Zavodskaya Laboratoriya*, 1957, **23**, (7), 813–817). Ultra-violet microscopy was used to investigate the surface of metals as well as of non-metals. The etching and polishing operations assume special importance in the preparation of the specimens. The description covers the investigation of a steel with Cr–Ni–Nb–C (inter alia) after anode etching, in an 8% solution of chromic anhydride, and the photograph of its microstructure is reproduced.

Film Supports and Replica Techniques for Electron Microscopy. R. Dargent. (*Métaux–Corrosion–Indust.*, 1957, **32**, Apr., 135–148; May, 191–200; June, 235–248). An illustrated description of the technique of film production is first given and factors influencing the type of film and the properties of different films are discussed. A review of replica techniques for studying surface structures is made and factors influencing the formation of pseudo surface structures, contrast, and resolution are considered. Techniques employed for the evaporation of SiO_2 and Al for shadowing are described. The preparation of the surface of the sample by cathodic pulverization or ionic bombardment is explained. (82 references).

Observation by Nitrocellulose Replicas of a Certain Type of Anisotropy in Metal Surfaces. P. A. Jacquet. (*Compt. Rend.*, 1957, **245**, Sept. 30, 1129–1132). The behaviour of polarized light on the surface of 18–8 steel and Al alloys after anodic oxidation in oxalic acid is exactly reproduced by nitrocellulose replicas metallized with Al.

On the Study of Microstructure of the Fracture of Metals by Electron Microscopy. III. On the Impact Fracture of Steels. H. Wakashima. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 55–58). [In Japanese]. Fracture surfaces of mild steel at temperatures down to — 70° C are flat and show domains large compared with grain size. Between 100° and 250° C the surfaces are very ductile. Above this temperature, the impact value falls off and the domains become smaller. With quenched high-carbon or Ni–Cr steel, fractures are flat, with ductile deformation and large domains. The surfaces of tempered Ni–Cr steel vary widely according to the cooling rate after tempering.—K. E. J.

Electron-Microscope Studies of Thin Layers of Iron. W. Pitsch. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 745–752). Iron layers of various thickness were deposited by evaporation on collodion carriers at room temperature and negative pressure. The collodion was separated from the resultant crystal blocks of about 50 Å edge length which were then annealed for various periods at 450 to 750° C.—L. J. L.

Universal Reagent for Macro-etching of Various Steels and Welding Seams. A. A. Rossokhinskii. (*Zavodska Laboratoriya*, 1957, **23**, (6), 750). [In Russian]. This reagent gives clear cut results. Experiments show that it reveals the macrostructure of low and high carbon alloys, high Cr and Mn alloys, Cr–Ni, nickel and austenitic steels as well as the welding seams from these steels. The high quality polish of the etched surface is also stressed.—L. H.

An Etching Method for the Differentiation of Chemically Resistant Chromium–Nickel and Chromium–Nickel–Molybdenum Steels. F. K. Naumann and W. Carius. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 641–644). Etching experiments were carried out with HCl and H_2SO_4 to which potassium ferrocyanide or ferricyanide had been added as an indicator for dissolved iron. It was possible to distinguish between Mo-containing and Mo-free acid-resistant Cr–Ni steels, highly coloured iron–cyanogen compounds being formed on the baser alloy.

The Submicroscopic Structure of "Ticonal" G Magnet Steel. H. B. Haanstra, J. J. de Jong, and J. M. G. Smeets. (*Philips Tech. Rev.*, 1957/58, **19**, (1), 11–14). Electron micrographs are shown of surfaces of the oriented magnetic alloy.

On a Method for the Direct Observation of Structural Fracture by the Electron Microscope. W. Pitsch. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 663–666). The direct printing process developed by J. Plateau, G. Henry, and C. Crussard (*J. Iron Steel Inst.*, 1956, **183**, 146–177) is described. The fractured surface is exposed to carbon vapour from two sources, an electric arc being ignited between two pointed carbon electrodes. The resulting carbon layer is lifted off by electrolysis, and washed in acetic acid and distilled water before being placed in the microscope.—L. J. L.

Non-Metallic Inclusions in Magnesium Cast Iron. A. E. Krivosheev and I. E. Lev. (*Lit. Proisv.*, 1957, **3**, (11), 18–19). [In Russian]. It was established by direct experiment that visible non-metallic inclusions contain MgS or its complex compounds, and that no compounds exist in which the presence of sulphur cannot be determined by the usual chemical methods of analysis for magnesium cast iron. There is therefore no doubt of the desulphurizing property of Mg. The sulphur of the cast iron forms MgS and in this form it separates from the metal.—L. H.

Determination of Electrochemical Indices for Microsegregation in Metals. A. Piotrowski. (*Arch. Hutn.*, 1953, **1**, (3/4), 373–415). [In Polish]. Potential oscillations in cells of two pieces of the same metal immersed in HNO_3 are studied. An expression is derived assuming that these are due to microsegregations and applied to steel and other metals. The values for steel ranged from 7·85–85·2 mV. The method may be of use in the control of heat treatment.

Non-Metallic Inclusions in Cast Iron with Spheroidal Graphite. P. P. Arsent'ev and Yu. Ya. Orlova. (*Lit. Proizv.*, 1957, (4), 23–24). [In Russian]. In the investigation described special attention was given to the determination of the mineralogical composition of inclusions, including those of Mg, in Mg-inoculated cast iron, and to the conditions of their formation. Specimens of the same iron before and after treatment with Mg and also after simultaneous treatment with Mg and Si were examined. Mg additions were 0·5%, the Fe–Si being added to give 0·6–0·7% Si in the iron. Details are given of the methods used to separate the inclusions and results obtained are tabulated and discussed. Mg-containing inclusions were found to form a comparatively small part of the total.—S. K.

The Electrochemical Principles of Isolating the Structural Constituents of Steels. W. Koch and H. Sundermann. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 557–566). The electrochemical conditions of the various isolation methods can be determined by recording current density-potential curves for steels and isolates, provided these latter are compounds having metallic conductivity. Alloyed and un-alloyed steels dissolve differently in the various neutral electrolytes. A distinction can be drawn between an iron (II)-active, an iron (II)-partly passive, and an iron (III)-active dissolution. Transition from one to the other is indicated by a shoulder in the current-density-potential curve.—L. J. L.

Influence of Interstitials on the Grain Size of α-Iron Obtained by $\gamma \rightarrow \alpha$ Transformation. M. de Jong and G. W. Rathenau. (*Acta Met.*, 1957, **5**, Nov., 679–680). Small amounts of C and N absorbed in the γ-phase in pure Fe reduced the α-grain size. Mechanisms are discussed.

Inspection of Free-Cutting Steel for Non-Metallic Inclusions. H. Hoff, G. von der Dunk, and H. Lessing. (*Stahl u. Eisen*, 1957, **77**, Sept. 5, 1210–1215). The authors studied the quantity and distribution of the non-metallic inclusions—oxides and sulphides—of 4–5-ton ingots of basic-Bessemer steel of composition: C 0·05, Mn 0·65, P 0·036, S 0·246, and Cu 0·06%. Compared with a similar ingot of O.H. steel the quantities of slag globules were five times larger in the basic-Bessemer than in the O.H. steel and the globule size of the inclusions were larger in the former. The results represented in a number of tables are discussed.—T. G.

Quantitative Determination of Martensite Formed in the Presence of Two Ferromagnetic Phases in the Alloy. F. A. Bogachev. (*Zavod. Lab.*, 1957, **23**, (8), 921–924). [In Russian]. A method is proposed by which the content of α-phase in an alloy can be determined not only during direct cooling but also during isothermal periods and the heating of the alloy.—L. H.

Secondary Hardness in Steels Alloyed with Vanadium, Molybdenum or Titanium. L. V. Zaslavskaya, S. T. Kishkin, N. F. Lashko, A. F. Platonova, N. M. Popova, and M. F. Rybina. (*Izvest. Akad. Nauk, SSSR, Seriya Fiz.*, 1956, **20**, (6), 684–688). [In Russian]. In the investigation described, the kinetics of the formation of carbides in the tempering of alloy steel were studied and related to the appearance of secondary hardness. New methods of differentiated carbide analysis, based on the selective chemical solution of the carbides in the anodic residue, were used. Steels with 0·1–0·8% C and 1·0–2·5% V or Ti, or 1·7% Mo were used, heat treatment being carried out in an argon atmosphere. X-Ray and magnetic methods were used to detect residual austenite. Hardness determinations were made and the results of these and of carbide investigations are related to tempering temperature for steels of various compositions.—S. K.

Investigation of the Ferrite Region of the Phase Diagram Fe–Co–O. J. Smiltens. (*J. Am. Chem. Soc.*, 1957, **79**, Sept. 20, 4881–4884).

On the Phases Occurring in Alloys of Aluminium with Iron and Silicon. I. Obinata and N. Komatsu. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 197–201). [In Japanese]. Various solubility and lattice data are given. In the Fe–Al system, $FeAl_3$ is in equilibrium with Al, which dissolves in it increasingly below 500° C. In the Al–Fe–Si system, α- and β-FeSi are in equilibrium with Al, but it is difficult to decide whether or not these phases have definite compositions. (30 references).—K. E. J.

On the Iron–Silicon–Antimony System. G. Zwingmann and R. Vogel. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 591–595). The above system has been studied by means of thermal and chemical analysis and structural analysis. The major part of the system is occupied by a miscibility gap in the liquid state. The equilibrium ratios were determined by a series of section diagrams.—L. J. L.

Phase Diagram of the Titanium–Iron System. I. I. Kornilov and N. G. Boriskina. (*Doklady A.N.*, 1956, **108**, (6), 1083–1085.

CORROSION

In the February 1958 issue, the last 3 abstracts in Col. 2 p. 198, beginning "Corrosion Mechanisms in the Plain Can" and the whole of p. 199 belong to the Corrosion Section, and not to Analysis, where they appear.

The Struggle Against Corrosion. F. Podbrežnik. (*Zaštita Mat.*, 1954, **2**, Jan., 4–10). A general account including non-metallic substances. **The Corrosion of Iron.** A. Horovic. (11–13). The question of archaeological objects found free from corrosive attack is discussed. Various non-corrosive environments are described.

Standardization in the Field of Corrosion and Corrosion-Protection in Germany. (*Corrosion*, 1957, **13**, Oct., 625–626; from *Metall*, 1955, **9**, July, 593). DIN standards for corrosion, corrosion testing, rust removal and protection by chemical and electrochemical coatings and testing of electrodeposits are tabulated.

Topochemical Studies of Corrosion Phenomena. W. Feitknecht. (*Corros. Anticorros.*, 1957, **5**, Feb., 36–50). The principles of the topochemical method for corrosion studies are described, with particular reference to rates of attack, properties of corrosion products and corrosion mechanism. Electron-microscopical and X-ray diffraction techniques for studying surface layers and corrosion products are given. (25 references).—B. P.

Atmospheric Corrosion of Metals at Low-Temperature. A. A. Dychko and K. A. Dychko. (*Zhur. Prikl. Khim.*, 1957, **30**, (2), 255–263). [In Russian]. In practical and theoretical investigations of atmospheric corrosion of metals, including cast iron and steels, a critical temperature of − 25° C has been established: below this atmospheric corrosion is sharply decreased.—S. K.

Oxide Patterns Appearing on the Surface of Molten Cast Iron. O. Madono. (*Giesserei* 1957, **44**, Nov. 21, 714–718). The possible structures of oxide films are explained by means of the FeO–SiO_2 phase diagram. The formation of films is influenced by temperature, chemical composition, atmosphere, and gases present in the melt. Si, C, and N_2 favour selective oxidation of Si, giving films rich in silica, whereas Mn enriches the FeO–MnO content of the film.—B. P.

Contribution to the Study of the Effect of Air on the Surfaces of Steel in Furnaces. D. Dančevic. (*Zaštita Mat.*, 1954, **2**, May-June, 142–146). Oxidation and decarbonization of Mo steel is related to composition, furnace atmosphere, and temperature. Decarbonization penetrates deeper than oxidation and failure under impact is possible if the layer affected is not removed.

Some Basic Problems of the Formation and Adherence of Scale on Iron. H. Engell and F. Wever. (*Acta Met.*, 1957, **5**, Dec., 695–702). Some kind of Kirkendall effect occurs due to preferential diffusion of either metal or O_2 in an oxide layer during scaling. If metal diffusion predominates the layer is porous; if O_2 diffusion, there will be a region of compression at the boundary facilitating removal of scale. In the layer of wüstite formed on iron only Fe diffuses between 600–850° C but porosity is rare. Adhesion in this case is maintained by plastic flow in the scaling layer. Near edges, on wires and on thin spirals complications occur. It can be shown that O_2 diffuses in over 850° C.

Investigations into the Structure and Adhesive Strength of Layers of Scale on the Unalloyed Steel Plate. H.-J. Engell and F.-K. Peters. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 567–574). The mechanical adhesion of rolling scale on unalloyed steels cast unkilled, or killed with Si and Al, and then rolled to plate of 10 to 27 mm thickness at rolling temperatures between 1050° and 650° has been studied by a method specifically developed for the purpose. With the unkilled steels, adhesion was found to decrease as the rolling temperature increased; no clear correlation was observed with the killed steels.—L. J. L.

Some Preliminary Results of an Electron Microscope Study of the Oxidation of Steels. A. M. Edwards and F. B. Pickering. (*J.I.S.I.*, 1958, May, **189**, 57–59). [This issue].

Contribution to the Study of Oxidation of Iron in Air between 700 and 1250° C. J. Paidassi. (*Rev. Mét.*, 1957, **54**, Aug., 569–585). The results described have been carried out on Armco iron and a special pure iron. The oxide film is shown to be formed of three continuous and compact layers of Fe_2O_3, Fe_3O_4, and FeO and the rate of growth is parabolic. In the range of temperatures studied the relative thickness of the three layers in relation to the total film thickness remains practically constant and in the ratio $1Fe_2O_3 : 4Fe_3O_4 : 95FeO$. The heat of activation, equivalent to 40,500 cal/gm.mol expresses equally the growth process of anyone of the three layers and that of the whole skin. (29 references).

Influence of Oxidation on the Chemical Composition of the Surface of High Temperature Alloys. F. Malamand and G. Vidal. (*Recherche Aéronaut.*, 1957, Feb., 47–57). The general theories of the build-up of oxide layers on metals exposed to oxidation at elevated temperatures are reviewed. The results of a series of tests on alloy steels and Nimonic alloys to measure the properties of the surface films are discussed.—B. O. B.

Corrosion of Metals with Incomplete Surface Layers. H.-J. Engell. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 753–760). The processes occurring in aerated salt solutions and in dilute acids are discussed, using the current density–potential diagrams of the base metal and the surface layer. The results of these theoretical calculations are confirmed by tests on iron sheet with incomplete surface layers of copper and silver.—L. J. L.

High Temperature Corrosion. S. Radovic. (*Zaštita Mat.*, 1954, **2**, Mar., 78–81). General theory is discussed related to partial oxygen pressure and the linear and parabolic laws. Methods of measurement of high-temperature corrosion resistance are outlined.

Rusting and Its Cost to Farming. E. E. White. (*Corros. Techn.*, 1957, **4**, Dec., 413–416). Slow-rusting materials and the effects of lime and fertilizers are considered.

Corrosion in Engineering. "Perseus." (*Corros. Prev.*, 1957, **4**, Oct., 44–52). The author discusses in general terms the corrosion problems encountered in the engineering industry and the steps taken to overcome them. Reference is made to the corrosion of external surfaces, and to the use of anti-corrosive paints and epoxy resins. Filiform corrosion is discussed and corrosion and adhesion testing techniques are compared. The author concludes with a consideration of preparation and pre-treatment.—L. E. W.

Corrosion Resistant Materials: Metals and Alloys. L. F. Spencer. (*Met. Fin.*, 1957, **55**, Oct., 58–62; Nov., 62–68). A review is given including stainless steels, their compositions, and susceptibility to intergranular attack and erosion. Rates of attack by H_2SO_4 on various steels and data for other acids and salts are tabulated. Ni and other alloys are then considered.

Corrosion Resistance of Stainless Steels. G. Colombo. (*Acciaio Inossid.*, 1957, **24**, July-Aug., 87–95). [In Italian]. Stainless steels are classified and their principal properties and corrosion resisting characteristics are reviewed. Four groups of steels are considered: Ni steels, Cr steels, Ni–Cr steels, and Cr–Mn and Cr–Ni–Mn steels. Both chemical and electrochemical corrosion are discussed as well as the phenomenon of passivity which gives these steels their remarkable corrosion resisting properties. Passivation techniques are briefly considered.

The Influence of Electrolytes in Corrosion. T. Markovic and B. Sribar. (*Zaštita Mat.*, 1954, **2**, Aug.-Sept., 201–203). The use of a Pt electrode for measurement of the aggressiveness of soil is described and the conditions for iron corrosion are studied. An equation with 2 constants is advanced.

Mechanism of Electrochemical Corrosion of Metals in Contact with Platinum–Electrolyte Systems. T. Markovic. (*Zaštita Mat.*, 1954, **2**, Mar., 83–86). The mechanism of corrosion in the Pt-electrolyte iron system is discussed.

Stress Corrosion Cracking of Insulated Austenitic Stainless Steel. A. W. Dana jun. (*Amer. Soc. Test. Mat. Bulletin*, 1957, Oct., 46–52). The phenomenon is supposed to be due to soluble chlorides leached from the insulation under moist conditions. Chlorides were detected in MgO, Ca silicates, and glass fibre. In simulated service tests 85% MgO produced the most corrosion.

The Relation between Pitting Corrosion and the Ferrous–Ferric Oxidation–Reduction Kinetics on Passive Surfaces. M. Stern. (*J. Electrochem. Soc.*, 1957, **104**, Oct., 600–606). Pitting on a number of passive alloys has been examined, only in the case of Ti is a very different exchange current shown. The local anodic polarization curve for solution under passive conditions is extremely steep and it is suggested that this is typical of the passive condition.

Fretting Corrosion as an Engineering Problem. K. H. R. Wright. (*Corros. Prev.*, 1957, **4**, Nov., 37–44). A review of processes and mechanism, quoting factors in the control of wear and the effects of different combinations of metals. Surface treatments and lubrication are discussed and the relationship to fatigue. (10 references).

Cavitation Corrosion. G. Ožbolt. (*Zaštita Mat.*, 1954, **2**, Aug.-Sept., 204–208). A review.

The Resistance of Cast Iron to Cavitation Erosion. R. I. Higgins. (*B.C.I.R.A., J. Res. Dev.*, 1957, **7**, Oct., 28–53). The author gives an account of tests carried out on a jet impact

machine and a magnetostriction apparatus. In the jet impact machine the specimens were rotated at high speed through a jet of water. The impact pressure was calculated to be about 7·5 t.s.i. In the magnetostriction apparatus the specimen was vibrated in water at a high frequency (10,000 cycles/sec.), but through a very small amplitude. The author concludes that the attack in the jet impact machine is largely mechanical. Within a homogeneous series of cast irons the order of merit increased with increase in tensile strength. The results from the magnetostriction apparatus show that an appreciable amount of corrosion attack occurred during the tests, particularly on unalloyed ferrous materials. Cathodic protection reduced, but did not eliminate, the total attack on the specimens. The author found no simple correlation between the results from the jet impact machine and the magnetostriction apparatus.—L. E. W.

Investigation into the Resistance to Cavitation Erosion of Zinc Coated and Nitrided Steel 38 X M YuA. I. N. Bogachev, Ya. M. Gitel'zon, T. M. Pogrebetskaya, and A. A. Yurgenson. (*Vestnik Mashin.*, 1957, (9), 24–26). Experiments showed that the nitrided surface of this particular steel has a great resistance to cavitation erosion after 50 h testing, whereas its non-nitrided surface subjected to heat treatment already shows intensive destruction after 3 h. Similarly the surface of the same steel electrolytically zinc plated shows double the resistance to erosion of the untreated surface.—L. H.

Role of Hydrogen Penetration in the Corrosion Fatigue of Steel. G. V. Karpenko. (*Doklady Akad. Nauk S.S.S.R.*, 1957, **113**, (4), 850–852). Experiments were carried out on samples of mild steel subjected to tensile strain while immersed in an acid electrolyte solution. The results are discussed.—S. I. T.

The Mechanism of Corrosion Product Formation on Steel and Zinc in a Humid Atmosphere Containing a Small Amount of HCl Vapour. K. Barton, E. Beránek, and S. Bartoňová. (*Chem. Listy*, 1957, **51**, (10), 1787–1790). [In Czech]. Corrosion was found to set in only after damage had occurred in the primary oxide layer. The composition of the corrosion products of zinc changes with time. Corrosion in the adsorbing layer of zinc takes place at significantly higher pH values then corresponds to the equilibrium concentration of HCl for vapour pressures of HCl in the atmosphere. This is ascribed to the buffering effects of the corrosion products. Similar effects in steel were much less pronounced.—P. F.

Investigations into the Stress-Corrosion Cracking in Welded Gas Plant. British Welding Research Association. (*Inst. Gas Eng. Comm.*, No. 517, 1957, Nov., pp. 16). Trials in NH_3 + HCN, with either CO_2 or H_2S or both, are reported on mild steel. A survey of gas works showed that cracking was common and could take place anywhere up to the outlet ammonia scrubbers. A range of compositions is defined within which cracking of stressed mild steel is probable.

The 'Intercrystalline Corrosion Known as 'Caustic Embrittlement' in Steam Boilers. M. Ardroer Iglesias and J. M. Hausmann Moro. (*Acero Energ.*, 1957, **24**, July-Aug., 35–51). [In Spanish]. The metallographic features of caustic embrittlement are illustrated, and the mechanism of this effect is discussed together with the factors influencing its behaviour. Some specific cases are outlined. The need for its recognition and control is stressed and full details of the Schroeder detector are given. The final part of the article is devoted to inhibitors of caustic embrittlement and analytical methods for their determination (sulphates, nitrates, tannins, and lignins). It is concluded that with perfect construction and adequate water conditioning, the problem is avoided; the different opinions that exist in regard to achieving the latter condition are discussed. (11 references).—P. S.

Deterioration of Boilers in Service. E. Abrahamsen. (*Jernindustri*, 1957, **38**, Sept., 165–171). The first of two articles. The author recapitulates well-known symptoms of deterioration (exterior and interior) of boilers in use, explains some of the causes and gives methods of reducing damage. Sketches indicate the commonest points of deterioration, suggestions are made for routine inspection, how repairs should be effected and when such cease to be worth while.

Corrosion of Food Cans. V. Crnčevic. (*Zaštita Mat.*, 1954, **2**, Mar., 71–77). Tin and Al container corrosion is discussed with methods of protection and a review of microorganisms which might be responsible.

Study of Changes in the Properties of Sea Water in a Corrosion Testing Installation. L. Barriety, J. Debyser, and A. Hache. (*Corros. Anticorros.*, 1957, **5**, Feb., 51–57). The rate and magnitude of variations in sea water depend on the volume isolated and on how long it is used. In summer it is impossible to keep the properties of sea water constant while in use. Studies in photosynthesis and the corrosion of steel by sea water are described; including the influence of pH, temperature, and dissolved O_2. The presence of algæ in the installation increases the oxygen content of the circulating water in summer.—R. P.

Electrochemical Determination of the Resistance to Corrosion of Welded Pieces of Low Alloy Steels. N. D. Tomashov, M. A. Vedeneeva, and Z. I. Vasil'eva. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 683–686). [In Russian]. The correlation between the corrosion resistance of the main metal and the seam of the weld is determined by the electrochemical potential of the various zones of the weld. For the rapid detection of the least corrosion resistance, the potentials were calculated along the intersecting lines of the various sections of the specimens with the seams of the joints. The composition of the electrolytes were also studied and a few solutions are recommended.—L. H.

The Corrosion Behaviour and Protective Value of Copper–Nickel–Chromium and Nickel–Chromium Coatings on Steel. C. H. Sample. (*Amer. Soc. Test. Mat. S.T.P.*, 197, 1957, 7–21, discussion 21–24). A sub-committee report on exposure tests is presented. The latter were superior to the former of the same total thickness, especially if the nickel was applied in two layers with an intermediate anneal or buffing treatment. The salt spray test did not show these effects.

The Standard Salt-Spray Test. Is it a Valid Acceptance Test? A. Mendizza. (*Amer. Soc. Test. Mat. S.T.P.*; 197, 1957, 107–117, discussion 118–129; *Plating*, 1957, **44**, Feb., 166–171, discussion 171–175). The test in its present form is unsuitable as a standard method. Minimum requirements for such a test are set out.

The Acetic Acid Salt Spray Test. J. H. Hooper. (*Electropl. Met. Fin.*, 1957, **10**, Dec., 403–408). Comparisons with other tests are made.

Some Experiments in Comparing the Resistance of Enamels to Corrosion by Alkaline Solutions. H. B. Kirkpatrick, E. L. McGandy, and J. C. Richmond. (*J. Amer. Ceram. Soc.*, 1957, **40**, Nov., 389–395). Sheet steel and cast iron enamels were tested in alkaline solutions and apparatus is designed with temperature control to ± 0·1° C and no exposure of glass to the solution. Temperature, concentration, and position of specimen in absence of agitation were studied. Ti-opacified enamels were included.

Scandinavian Co-operation on Methods for Short Term Testing of Anti-Rust Paints. P. Nylen. (*IVA*, 1957, **28**, (2), 101–104). The four Scandinavian countries have since 1954 been co-operating in research into the prevention of corrosion. Details are given of metal plate and paints used. These are always of the same quality. Methods of application and other procedural data are described. The effects of weather, salt, tropical conditions, and corrosive gases are under study.

Artificial Insulating Joints for Stray Current Mitigative Measurements. G. H. Cantwell. (*Corrosion*, 1957, **13**, Oct., 616–618). A method of simulation for determining the effect of such a joint is given which makes temporary insertion unnecessary. Earth resistance, and potential to earth at each side of the joint are also found.

Reduction of Cavitation Pitting of Diesel-Engine Cylinder Liners. J. A. Joyner. (*S.A.E. Trans.*, 1957, **65**, 337–348). Ni–Cr plating is recommended. Measures reducing vibration eliminated pitting.

New Ways to Fight Corrosion. (*Steel*, 1957, **141**, Aug. 26, 68–71). Modern practice in combating corrosion is described. The fields considered are cathodic protection, coatings, inhibitors, and resistant materials. The use of technetium (element 43) as an inhibitor is mentioned.—D. L. G. P.

Corrosion Prevention Starts with Design. H. P. Godard. (*Ind. Eng. Chem.*, 1957, **49**, Nov., 79A–81A). Factors affecting corrosion rate are discussed. Design may be more important than the inherent resistance of the metal, especially for galvanic and crevice corrosion.

The Present Position of Techniques for the Protection of Metals Against Corrosion. P. Orlowski. (*Génie Civil*, 1957, **134**, May 15, 227–231). The theories of protection by cathodic means and by protective coatings are outlined and the principal methods are indicated. Testing methods are also reviewed.

Protection from Corrosion of Metals during Intermediate Operations. J. Verčon. (*Zaštita Mat.*, 1954, **2**, Oct., 248–251). Protection of metals during machining and assembly is reviewed and the use of temporary coatings described.

Preventing Metal Corrosion in Building. M. Blažon. (*Zaštita Mat.*, 1954, **2**, Apr., 108–112). Metals have usually only a short life in building constructions or, like copper, are too dear. Use of Al and alloys is surveyed, and cathodic protection and the use of protective coatings.

Contribution to the Theory of Cathodic Protection. II. C. Wagner. (*J. Electrochem. Soc.*, 1957, **104**, Oct., 631–637). Distribution of potential inside a solution is calculated for typical cathodic protection systems. It is shown that there are conditions where the local single electrode potential differences are low enough to give complete protection without H_2 evolution, using automatic control of the impressed current.

Cathodic Protection for the Chemical Industry. C. L. Wilson. (*Chem. Proc. Eng.*, 1957, **38**, Oct., 394–395). Applications to condensers, tanks, autoclaves, pumps, valves, and the inside of pipes are indicated.

Cathodic Protection of Brewery Liquor Tanks. A. W. Hubbard. (*Corros. Prev.*, 1957, **4**, Oct., 57–58). The author gives an example of the successful application of cathodic protection to brewery liquor tanks. Graphite anodes were employed and were mounted on insulating stands which were bolted into the bottom of the tanks.—L. E. W.

The Protection of a Sulphonating Plant. T. P. Barling. (*Corros. Prev.*, 1957, **4**, Oct., 61–63). The author describes how corrosion is being successfully overcome by the three-coat "Epiglo" system. The surface preparation is indicated and the results obtained with test patches located in different parts of the plant are outlined.—L. E. W.

The Use of a Desiccant for Protection Against Atmospheric Corrosion. S. Radomir. (*Zaštita Mat.*, 1954, July, 182–187). Corrosion due to dampness is discussed and the use of silica gel described.

Inhibitors of Corrosion. M. Darrin. (*Ing. e Indust.*, 1956, **24**, Nov., 101–107). [In Spanish]. Six methods of inhibitory control of corrosion in water recirculating systems are discussed in turn. Recommended chromate additions for various industrial applications are listed. Some brief attention is given to the possibilities of aggravating corrosive attack, and some data for the corrosion of steel in salt solutions with chromate additions are added. (16 references).—P. S.

A Laboratory Study of *N*-Oleoyl Sarcosine as a Rust Inhibitor in Some Petroleum Products. R. M. Pines and J. D. Spivack. (*Corrosion*, 1957, **13**, Oct., 690–694). In petrol, mineral oil, and silicone lubricants the compound was effective. Three standard tests were used and its effect on other properties was observed. Resistance to synthetic sea water and to water extraction was high.

ANALYSIS

Analysis of Pure Metals. V. A. Nazarenko. (*Zavods. Lab.*, 1957, **23**, (10), 1162–1167). A review, 1917–57, with 44 references.

Studies on the Allowance of the Chemical Analysis of Ferro-alloys by JIS Methods. II. Ferrosilicon. T. Imai and S. Togashi. (*Nippon Kinzoku*, 1956, **20**, Feb., 77–80). [In Japanese]. Errors introduced into a number of standard methods for Si, C, P, and S, caused by segregation or analytical procedures, are assessed quantitatively. (23 references).—K. E. J.

5 Minute Wet Analysis Speeds Steelmaking. K. Jacobsen. (*Mod. Castings*, 1957, **32**, Nov., 49). An illustrated indication of sampling and methods for C, Mn, and S.

Technological Preparation of Samples of O.H. Furnace Melts for Rapid Analysis. G. A. Klemeshov. (*Zavodskaya Laboratoriya*, 1957, **23**, (7), 870). [In Russian]. A method is here described for substituting small melts for forged specimens for a rapid and satisfactory analysis with a substantial saving of time and without losing any of the precision required for reliable results.—L. H.

Photometric Analysis in the Iron and Steel Laboratory. T. Sotlar. (*Nova Proizv.*, 1954, **5**, (3–4), 260–263). Control at the Jesenice works is described.

Analysis of Pig Iron and Cast Iron Residues. A. Wittmoser, H. Bookshammer, and W. D. Gras. (*Rev. Mét.*, 1957, **54**, May, 369–382; June, 419–432). A description is given of a new technique in which efforts have been made to dissolve entirely the specimen, in the shape of a disc employed as an anode. Sodium citrate solution containing a wetting agent was used as an electrolyte. A magnetic technique is employed to remove the cementite after which it is possible to separate graphite from the oxide residues by flotation. Examples are shown of the type of separations possible by the method.—B. G. B.

The Separation, Purification and Recovery of Metals by Means of Ion-Exchangers. G. Montel. (*Chim. Ind.*, 1957, **78**, Nov., 451–459).

Checking the Composition of Liquid Cast Iron from the Depth of Decarburisation of Technological Samples. M. L. Vinokur. (*Lit. Proizv.*, 1957, (9), 30–31). [In Russian]. It has been found possible to estimate the silicon content of cast iron from the depth of the light-coloured layer formed on casting samples in semi-chill moulds sufficiently accurately for process control purposes. The method is described.

Determination of Gases in Cast Iron. T. Shimomura and M. Yamamoto. (*Tetsu to Hagane*, 1957, **43**, May, 569–574). [In Japanese]. The vacuum fusion method and the vacuum heating method are compared, and the optimum conditions for conducting the former and for taking samples are derived.

Comparative Estimation of Methods for the Determination of Gases in Steels. Yu. A. Klyachko, L. L. Kunin, and E. M. Chistyakova. (*Zavodskaya Laboratoriya*, 1957, **23**, (8), 905–907). [In Russian]. Two instruments have been tested for vacuum fusion; a furnace apparatus with a volumetric analyser and an apparatus with high-frequency heating analysing under pressure at constant volume. It has been found expedient to use the latter apparatus for metals containing from 0·5 to 5 cm³ of gases per 100 g of metal, to use either for gas contents between 5 and 25 cm³, and the former for contents above 25 cm³.—L. H.

The Solubility of Oxygen in Liquid Nickel and in Liquid Solutions of Iron and Nickel. W. P. Fiedotow and A. M. Samarin. (*Arch. Hutn.*, 1956, **1**, (3), 183–193).

The Determination of Hydrogen in Solid and Liquid Pig Iron. I. General and Experimental Section. K. Zimmermann. **II. Results to Date on the Hydrogen Content of Pig Iron.** H. Uhlitzsch. (*Neue Hütte*, 1957, **2**, Oct., 607–616). New apparatus for taking and analysing samples of liquid pig iron for the purpose of H_2 determination, and a novel tube for the combustion of the gases extracted with O_2 are described. Results are reported on solid pig iron feeders and H_2 contents of liquid pig iron.—L. J. L.

Hydrogen Content and Its Determination in Cast Iron Melted in an Experimental Cupola. J. Václavínek. (*Slevarenství*, 1957, **5**, (10), 83–90). A vacuum apparatus was constructed for H_2 determination and grey cast irons from a 160 mm cupola were examined. Degasification can be carried out by additions of ilmenite or soda with limestone. In the cupola with acid lining and cold blast a lower gas content is obtained than in the basic cupola and preheated blast also helps degasification. The degasified irons usually have better physical properties.

Cerimetric Titration of Iron Using a Mixed Indicator. W. R. Heumann and B. Belovic. (*Anal. Chem.*, 1957, **29**, Aug., 1226–1227). The sharp change of 1 : 10-phenanthroline is led up to by the addition of diphenylaminesulphonic acid.

Colorimetric Determination of the Combined Carbon in Low Alloy Structural Steels. L. V. Zaslavskaya and N. M. Popova. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 656–657). [In Russian]. The method allows the determination of very small quantities of combined carbon, which makes it suitable for zone analysis. With the help of the standard graphs, the resulting relation between the contents of the combined carbon and the intensity of colour has been satisfactorily determined on specimens of 30 X steel subjected to various heat treatments.—L. H.

The Determination of Cobalt in Steels and Ores. J. Doležal and J. Novák. (*Chem. Listy*, 1957, **51**, (10), 1798–1803). [In Czech]. A rapid polarographic method for determining Co in the presence of Fe, Al, Cr, Mn, Ni, Zn, V, Mo, and W was developed. The reaction is based on the formation of a complex between Co and ethylenediamine in alkaline solutions. The method was successfully applied to analyses of steels and ores.—P. F.

Remarks on the Photometric Method for Nickel Using Dimethylglyoxime. Z. Gregorowicz, S. Grochowski, and J. Kubala. (*Chem. Analityczna*, 1957, **2**, (4), 322–326). Volume and concentration effects and colour stability are investigated.

Constant Current Potentiometric Determination of Manganese. C. O. Huber and I. Shain. (*Anal. Chem.*, 1957, **29**, Aug., 1178–1180). The Volhard method is improved but the end-point of the Lingane–Korplus method is as precise as in the potentiometric procedure.

Bromine-Methyl Orange Method for the Determination of Manganese in High-alloy Steel and Duralumin. L. G. Gein. (*Zur. Anal. Khim.*, 1957, **12**, (3), 422–423). [In Russian]. The principle of the method here described is based on the fact that bromide ions are easily oxidized with MnO_4^{--} even in a weakly acid medium, whilst they are oxidized with difficulty or not at all by the ions of the other components of steel, even in more acid media. The bromine liberated on oxidation can be titrated in 0·1–3 N H_2SO_4 in the presence of an aqueous solution of Methyl Orange.—L. H.

Separation of Molybdenum from Iron, Aluminium and Calcium with the Help of Anion-Exchangers. Yu. V. Morachevskii and M. N. Gordeeva. (*Zavods. Lab.*, 1957, **23**, (9), 1066–1067). [In Russian]. The article describes experiments for the separation of Mo from Fe, Al, and Ca from HNO_3 and HCl solutions with anion exchange resin PE–9.—L. H.

An Accurate Potentiometric Method for Determining Vanadium (V_2O_5) and a Review of other Volumetric Methods. L. Block and R. A. J. Thienpont. (*Chem. Week.*, 1957, **53**, Aug. 3, 421–6). [In Dutch]. The authors report on a potentiometric method they have developed for determining accurately the V content of various ores originating from S.W. Africa. Comparisons are made with the results obtained by other methods and the article concludes with complete analytical results of the ores examined. (17 refs.).—P. R. H.

The Determination of Small Titanium Contents in Iron Alloys and Ores After the Separation of Heavy Metals with Pyrrolidine-dithiocarbamate. E. Schöffmann and H. Malissa. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 623–624). A description is given of a method by which all the elements that interfere with Ti determination by H_2O_2 are extracted by shaking with pyrrolidine-dithiocarbamic acid and chloroform, whereupon the Ti is determined as peroxytitanyl ion. By this method, traces of Ti in iron ores, pig iron, or in alloyed and unalloyed steels can be accurately determined even in the presence of V and W.—L. J. L.

Separation of Titanium from Accompanying Elements by Ion Exchange Chromatography. I. P. Alimarin, T. A. Belyavskaya, and L. A. Bazhanova. (*Zhur. Anal. Khim.*, 1957, **12**, (3), 377–380). [In Russian]. The partition coefficients are calculated by the formula: $\phi = M_1/(M - M_1) \times V/m$, M_1 being the fraction of the element in the resin, M the quantity of the element in the original solution and V the volume of the solution, m being the mass of the resin. A method is described for partition coefficients between ion exchange resins and HCl and H_2SO_4 of different normalities; ammonium thiocyanate solutions of various concentrations and a ½% solution of Complexone III of different pH values for quadrivalent Ti and trivalent Cr. The quantitative chromatographic separation of Ti and Cr is also given for ratios of Ti to Cr from 1 : 100 to 10,000 : 1.—L. H.

Determination of Lower Titanium Oxides in the Presence of Bivalent Iron. L. I. Veselago. (*Zhur. Anal. Khim.*, 1957, **12**, (3), 381–385). [In Russian]. The method described has been evolved for the determination of the sum of the lower Ti oxides contained in slags with FeO. The accuracy is not greater than 1·5% but it is sufficient for giving the Ti content. Since reduced Ti is very unstable, it is recommended that the decomposition of slags should take place in the presence of quinquevalent V, quadrivalent Ce or the trivalent iron. The best method for the determination of FeO in the presence of Ti is by using Na_2WO_4.—L. H.

The Use of Benzenesulphinic Acid for the Determination of Zirconium. I. P. Alimarin and S. S. Alikberov. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 658–660). This acid can be considered as the group reagent for quadrivalent elements. The selectivity could be increased if reactions were done in acid solution. The reaction is very sensitive and the compound has a very low solubility.—L. H.

The Determination of Aluminium in Cast Iron and Ferro-Silicon by the Fluoride Volumetric Method. W. E. Clarke and R. C. Rooney. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, June, 666–669). After appropriate solution techniques the major part of the iron is removed by a butyl acetate separation and other interfering elements by a diethyldithiocarbamate-chloroform extraction. The pH of the solution is then adjusted, fluoride added and the liberated hydroxyl-ion, which corresponds to the amount of aluminium present, is determined acidimetrically.—B. G. B.

Determination of Arsenic in Iron and Steel. S. Wakamatsu. (*Tetsu to Hagane*, 1957, **43**, May, 565–569). [In Japanese]. The accuracy of the $SnCl_2$ reduction method is increased by effecting the reduction of As in 12N HCl at 45° C.—K. E. J.

Analysis of Carbides Extracted from Steel. J. D. Hobson. (*Analyst*, 1957, **82**, Oct., 708–710). Totals never reached 100% with an error greater than that expected in the analyses. Various sources of error were examined and oxidation appears to occur in electrolytic extraction. Methods are given and many analyses are tabulated.

Photocolorimetric Determination of Cr_2O_3 with Complexone III in Chromite-Magnesite, and in Magnesite-Chromite Articles and in Chromium Ores. A. M. Pinus. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 662–663).

On the Precision and Rapidity of Some Chemical and Physical Determinations of Alumina in Aluminosilicates. I. A. Voinovitch and J. Debras. (*Chim. Anal.*, 1957, **39**, Nov., 418–428). Volumetric determination using oxine is recommended.

A Rapid Method for the Analysis of Blast Furnace Slags. P. I. Protsenko. (*Zavodskaya Laboratoriya*, 1957, **23**, (8), 911–912). [In Russian]. A method is described combining volumetric and colorimetric procedures giving the result within 20 min of a satisfactory analysis.—L. H.

Rapid Complete Analysis of Cupola Slag. B. Bieber and Z. Večeřa. (*Slévárenství*, 1957, **5**, (9), 73–82). [In Czech]. A new rapid method

requiring about 2 h for completion is described. Silica is determined gravimetrically after evaporation with ammonia, iron is determined photometrically using KCNS, alumina is determined complexiometrically, and this method is also applied to TiO_2, CaO, and MgO. Na, K, and P are determined photometrically. The method is applicable also to blast-furnace and other steelworks slags.—P. F.

Spectrographic Analysis of Slags. B.I.S.R.A. Methods of Analysis Committee. (*J.I.S.I.*, 1958, May. **189**, 49–55). [This issue].

Photometric Determination of Alkalies in Sintered Alumina. M. Bartuška, J. Hlavač, and S. Procházka. (*Silikáty*, 1957, **1**, (1), 87). [In Czech]. Corundum was quantitatively decomposed by heating with a mixture of lithium carbonate and hydrated boric acid. The total alkali content was thus converted and subsequently determined photometrically. With Na_2O and K_2O an accuracy of 0·03% was obtained.—P. F.

Polarographic Reduction of Ferric Ions in the Presence of Ethylenediaminetetra-acetic Acid and Hydrogen Peroxide. III. The Reaction of Hydrogen Peroxide with Ethanol. B. Matyska and F. P. Dousek. (*Chem. Listy*, 1957, **51**, (10), 1791–1797). [In Czech].—P. F.

Magnetic Moment of Iron Ions. S. Broersma. (*J. Chem. Phys.*, 1957, **26**, June, 1405–1406). Proton magnetic relaxation rates were measured in perchlorate solutions at pH 0–12. The moments of $Fe(OH)^+$, $Fe(OH)^{++}$ and Fe^{+++} are equal at 5·9 Bohr magnetrons while $Fe_3(OH)_3^{++++}$ is diamagnetic.

Recommended Methods for the Analysis of Trade Effluents. Methods for the Determination of Antimony, Barium Soluble in Dilute Hydrochloric Acid and Cadmium. Joint A.B.C.M.–S.A.C. Committee on Methods of Analysis of Trade Effluents. (*Analyst*, 1957, **82**, Nov., 764–767).

Optical Spectra of Hydrated Ions of the Transition Metals. O. G. Holmes and D. S. McClure. (*J. Chem. Phys.*, 1957, **26**, June, 1686–1694). Ferrous ion was examined in $FeSO_4$, $7H_2O$. The results disagree with previous measurements.

Fuess Spectroscope for Qualitative and Quantitative Spectrochemical Analysis. (*Spectr. News*, 1957, **10**, July-Aug.-Sept., 1–3). Examples of low-alloy and stainless steel analyses are given.

New Standards for Test Specimens and for Spectro-analysis. V. V. Stepin. (*Zavodskaya Laboratoriya*, 1956, **22**, (11), 1391–1393). [In Russian]. This is a list of new standards issued by the Institute of Standards Laboratory of the Ural Institute for Ferrous metals. It has many headings, but refers to the spectro-analytical standards included in the issue of *Zavodska Laboratoriya* of 1953.—L. H.

Regarding the Precision of the Photographic Method of Spectrum Analysis. V. L. Ginzburg, E. F. Alekseenko, E. E. Belorinitskaya, I. N. Vitushkina and F. M. Ineshina. (*Zavodskaya Laboratorya*, 1956, **22**, (11), 1331–1332). [In Russian]. This is a comparison between the 3-standard method and the procedure of calibration curves. The first diminishes the influence of the variable factor (γ) in the results of the analysis whilst the second allows mistakes due to chance changes in the excitation of the spectrum. In the estimation of the photographic results, the quality of the materials should be taken into account. In the tests described three different types of plates were used and tests made with 10–15 plates for each type. The tabulated results show the margins of error.—L. H.

A Test with Photoelectric Apparatus in Spectro-analysis at the "Sickle & Hammer" Factory. I. M. Veselovskaya. (*Zavodskaya Laboratorya*, 1956, **22**, (11), 1378–1383). [In Russian]. The FESA 4M apparatus is shown together with the amplifying circuit of the instrument. Tests are fully described and the results recorded on tables and graphs. The tests are from actual practice and have been carried out at the factory.—L. H.

Present State of Steel Analysis by the Quantometer. G. Hartleif. (**Stahl u. Eisen*, 1957, **77**, Oct. 17, 1497–1499). The author discusses whether it is more advantageous to employ one universal instrument or several smaller instruments for a specific task in a steel works.—T. G.

The Spectrographic Determination of Trace Elements in Steel with Moving Electrodes. S. Eckhard and W. Koch. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 731–738). In the determination of trace elements in steel, the spectrographic investigation is usually preceded by chemical enrichment processes if sensitivity, in the direct investigation of the samples, is found to be inadequate. With some elements, the sensitivity in direct investigation can however be noticeably increased by using mobile electrodes.—L. J. L.

A New Method of Precise and Quantitative Spectrographic Analysis without an Internal Standard. Application to Iron. A. Rodriguez Perez. (*Inst. Hierro Acero*, 1957, **10**, Apr.-June, 166–170). [In Spanish]. A large number of Fe lines have been studied in relation to their intensity/concentration curves. Details of the experimental technique are given; the majority of the lines measured were between 4300 and 2700 Å. Three line-pairs that give excellent working curves for various iron concentrations are given, these are: 3727.621 and 3020.645, 3570.10 and 3020.645, and 2719.027 with 2749.322. Other suitable pairs for high and for very low concentrations are given.—P. S.

Spectrochemical Determination of Silicon in High and Low Alloy Steels. H. Carrancio de la Plaza. (*Inst. Hierro Acero*, 1957, **10**, Apr.-June, 195–199). [In Spanish]. The author has studied the quantitative determination of Si by the Gerlach method and by using line pairs. He concludes that: (i) the presence of a third element does not affect the determination in high alloy steels by classical methods, (ii) better results are obtained by using an internal standard rather than the intensity comparison of two Si lines, and (iii) a single pair of lines (2881.568 Si I and 2880.756 Fe II) gives excellent results over the range 0·10 to 2·85% Si.—P. S.

Study of K-Edge Absorption of Chromium in α- and σ-Phases in the System of Fe–Cr Alloys. V. A. Kazantsev. (*Doklady A.N.*, 1957, **115**, (3), 501–503). The K-edge absorption of Cr phases was photographed by means of a high-vacuum and high power spectrograph with a curved crystal. This study of atomic structure of Cr phases throws light on the phase α–σ transformation. The spectrographic results are interpreted in terms of energy levels of the atoms. It is also suggested that at a high temperature there is a certain number of electrons passing from chromium to iron.

X-Ray Spectrographic Methods of Investigation of Local Chemical Composition. I. B. Borovskii and N. P. Il'in. (*Zavods. Lab.*, 1957, **23**, (10), 1234–1242).

"Point-Probe Microanalysis." (*Sheet Met. Ind.*, 1957, **34**, Nov., 818). An electron beam excites emission from a region a few μ in dia. and the X-rays are analysed by a crystal spectrometer. The apparatus is a modified electron microscope.

The Quantitative Determination of Alloy Elements in Steel By Means of X-Ray Fluorescence Spectrum Analysis. H. Krachter and W. Jager. (**Arch. Eisenhütten.*, 1957, **28**, Oct., 633–639). The principles of X-ray fluorescence spectrum analysis are described. The effects on accuracy of measurement of thickness of sample, the character of the surface, and duration of measurement are examined in detail. Tests on high and low alloy steels have shown that strong mutual interaction of the elements exists in all cases. It is therefore advisable, in the quantitative analysis of alloy steels, to rely on comparison with samples of similar, but known, composition.—L. J. L.

The Application of Radioactive Tracers to Surface Studies. R. W. Cahn. (*Bull. Inst. Met. Finish.*, 1957, **7**, Autumn, 1–12). Methods are outlined and studies of exchange, adsorption, and corrosion are reviewed, also electroplating and metal transfer in friction. (26 references).

Radioisotopes: Use Them on Tough Problems. C. M. Crompton. (*Iron Age*, 1957, **180**, Oct. 17, 111–114). A survey is made of techniques involving radioactive materials, which are of use to the metal industries. Applications mentioned include: measurement and control of strip and coating thicknesses down to 0·0001 in.; measurement of thickness of a vacuum coat film to 10^{-12} in.; study of wear, metallurgical research.—D. L. C. P.

INDUSTRIAL USES AND APPLICATIONS

General Principles Governing the Choice of Materials. N. P. Allen. (*Tekn. Ukeb.*, 1957, **104**, Sept. 12, 735–742). [In English]. Choice of metals is discussed in terms of availability, fabrication, and service life.

Metallic Materials of Construction. M. Birkhead. (*Chem. Proc. Eng.*, 1957, **38**, Oct., 396–398). Uses of steels and other metals for chemical plant, with special reference to fabrication, are given.

On the Choice of the Structure of Steel for Machine Parts Subjected to Cyclic Impacts. I. L. Mirkin and E. D. Tsypkina. (*Vestnik Mashin.*, 1955, (1), 72–75). [In Russian]. For many important machine parts working under conditions of cyclic impact, such as connecting rods, crankshafts, etc. the use of medium carbon- and light alloy highly tempered steel is recommended, instead of low carbon, and high alloy steel in a low tempered condition.—L. H.

Steel Tubular Products. (*A.I.S.I. Steel Prod. Man.*, 1957, Sept., pp. 155).

The Railways and the Steel Industry. J. E. Hartshorn. (*Steel Rev.*, 1957, July, 40–45). A general estimate of steel requirements is presented.

Comparison between Steel and Aluminium Passenger Vehicles—I. L. W. Bardsley. (*Rail. Gaz.*, 1957, **107**, Aug. 9, 158–159; Sept. 13, 307–308). An account of rolling stock on the Toronto Underground is given. Structure, weight and power consumption are considered, also the reduced wear of brake shoes, bearings, wheels, and bodies due to reduced weight. Resistance to corrosion is also a factor.

Stainless Steels: Problem or Opportunity. H. J. Nichols. (*Can. Metalw.*, 1957, **20**, Oct., 50–52). A review of fabrication problems which, it is said, the industry neglects to solve.

Maximum Economy Design of Compound Steel Sections Eccentrically Loaded. F. de Miranda and C. Berardi. (*Acciaio Costr. Met.*, 1957, **9**, July-Aug., 154–162). [In Italian]. The authors develop a design formula for axially loaded fabricated struts. Normal and eccentric loading is considered and both stability and buckling are taken into account. A numerical example is worked out and nomograms are given which enable loading dimensions to be readily determined.—M. D. J. B.

Percussion Drill Steel Life. I. L. E. Antonides. **II.** B. F. Shepherd. **III.** F. R. Anderson. **IV.** T. W. Wlodek. (*Eng. Min. J.*, 1957, **158**, Nov., 90–97). Compositions, heat treatment, and service life tests are given and fatigue test data are added. (26 references).

Rails Made from L.D. Steel. H. Laizner. (*Zeitschrift des Oesterreichischen Stahlbauvereines*, 1957, (2), 29–31). Test results are reported.

Steam Turbines for High Steam Temperatures and Pressures. C. Brennecke and R. Schinn. (*V.D.I.Z.*, 1957, **99**, Aug. 21, 1165–1171). Topics discussed in connection with steels used in existing installations include creep, machinability, resistance to scaling. **Part II.** (Sept. 1, 1233–1244). In this part the steels used are discussed in detail. Alloys employed in various installations are tabulated, statistics of failures are quoted, and particular forms of failure and their relation to structure are discussed. **Turbines with Working Temperatures of 593° C and Above.** (Sept. 11, 1275–1283). Design and material requirements are formulated from an analysis of eight proven installations working in range 593–650° C below and over critical pressures. Particulars of steels proposed for the various components are tabulated, including some data on mechanical properties. **Part II.** (Sept. 21, 1335–1342). Ten further installations are reviewed and the steels used are tabulated, parts and microstructures are shown and working conditions are indicated.

Steel Purifier Grids. (*Coke Gas*, 1957, **19**, Nov., 458–461). Gasworks purifier grids installed at Liverpool are reported on. They proved much more economical than wood.

Oil Production and the Steel Industry. E. S. Tucker. (*Steel Rev.*, 1957, Jan., 35–42). An estimate of steel requirements by the petroleum industry is given.

Stainless Steels for the Petroleum Industry. F. A. Kirk and J. Williams. (*Federation of European Petroleum Equipment Manufacturers, Stuttgart, reprint*, 1957, Oct., pp. 16). British and U.S. corrosion- and heat-resisting steels are compared in tables and specifications. Chromium steels, 5, 7, 9, 13, 17, 20, and 27% Cr; austenitic Cr–Ni steels 18%, 18/10, 25/12, and 25/20; and high-Cr Fe alloys, high-Mn, precipitation hardening types and Cu-bearing; and specifications are quoted for billets, bars, wire, forgings, plates, sheet and strip, pipes and tubes and castings. Mechanical properties and creep are also discussed.

Stainless Hopper Cars Stand Long Service. J. Halbig and R. K. Thompson. (*Iron Age*, 1957, **180**, Oct. 17, 118–119). The condition of 2 stainless steel lined coal wagons after 20 years service is described. Both are in satisfactory condition and maintenance costs are low. One wagon has $\frac{3}{16}$ in. thick corrugated plates, the other $\frac{1}{4}$ in. thick pan-type panels.

Choice of Alloy for Electric Radiant Heaters. E. Segre. (*Acciaio Inossid.*, 1957, **24**, July-Aug., 96–97). [In Italian]. Various types of heaters are considered and where maximum temperatures rise to 1100–1150° C a 75% Ni, 15% Cr, and 10% Fe alloy is recommended. Progressively less and less nickel can be used with lower temperature requirements and where these are in the range of 850–880° C the recommended alloy is 9% Ni, 18% Cr, Ti, and 73% Fe.—M. D. J. B.

Iron–Nickel–Cobalt Alloys for Glass–Metal Connections. H. Herrmann and H. Thomas. (*Z. Metallk.*, 1957, **48**, Nov., 582–587). Five Fe–Ni–Cr alloys containing 27–30% Ni and 17–18% Co were selected, and the α–γ transformation investigated by polarization-optical methods and measurements of the electrical resistance.—L. D. H.

HISTORICAL

Abraham Darby (I and II) and Coal–Iron Industry. R. A. Mott. (*Trans. Newcomen Soc., preprint*, 1957, Nov. 21, pp. 42). After an introduction on the charcoal–iron industry, the uses and quality of coal and Coalbrookdale, evidence is presented for the date of the beginning of smelting with coke and of the furnaces and processes used. The contributions made by father and son are separated and the former shown to be the great pioneer.

The Catalan Forges and Their Associated Industries. L. Gonzalez Diaz. (*Met. Elect.*, 1957, **21**, Oct., 61–70). [In Spanish]. Details of the Catalan Forges of the Ripoll district in the Pyrenees are given. The author discusses the location, construction, and operation of these, and points out that they existed from the 9th or 10th centuries until the last one, at Campdevanol, closed in 1878. In their heyday they supported many 'factories,' at least 150 are listed in the Ripoll museum, mainly concerned with the manufacture of arms. Reconstructed Forges can be seen at Legazpia and Ripoll.—P. S.

Data on the History of Metallurgy in Hungary. Manufacture of Pig Iron from High-Alumina Ores in the 18th Century. A. Schleicher. (*Acta Tech.*, 1957, **18**, 3/4, 427–431). [In English].

Working in Iron at Jesenice. A Short Historical Outline. S. Slavko. (*Nova Proizv.*, 1954, **5**, (3–4), 145–165). The origins and development, and the technical, economic and social problems of the valley are outlined. The foundation of the Industrial Society of Carniola is also investigated.

Experimental Studies Carried Out On The Wrought Iron Garibaldi Bridge in Rome. A. Berio and N. Collari. (*Acciaio Costr. Met.*, 1957, **9**, July-Aug., 163–171). [In Italian]. A detailed account is given of a report specially prepared to determine the safety of the old Garibaldi Bridge in Rome. The bridge built in 1885 is of wrought iron. The researches include investigations into the metal's chemical composition, metallographic properties, mechanical strength, ageing, resistance to shock, and fatigue. (15 references).—M. D. J. B.

The Examination of a Broadsword from Luristan. F. K. Naumann. (*Arch. Eisenhütten.*, 1957, **28**, Sept., 575–581). A report is given of the application of a variety of methods of non-destructive testing to a sword found in Northern Syria and attributed to the 7th century B.C. Archaeologists had surmised that the sword was of cast iron which would have put back the discovery of iron casting by some 300 years from the accepted date. It was shown that the sword is composed "of a multiplicity of parts" and cannot have been made, in part or as a whole, by casting.

Preliminary Investigation of Ancient Metallurgical Slags Collected in Some Parts of Poland. S. Holewinski. (*Arch. Hutn.*, 1956, **1**, (3), 251–281). A brief description of the ancient history of iron and investigations abroad is followed by an account of preliminary archaeological studies in Central Poland. Analyses are given and macro- and microstructures are shown. It is concluded that the technology was similar in many parts of Europe. The supposed succession of operations is given.

Art Iron Castings Around 1800. S. Theisen. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1499–1505). (Illustrated).—T. G.

ECONOMICS AND STATISTICS

Steel: World Report. 1. The American Steel Industry. 2. Export Premiums or Home Discounts. 3. Coastal Steelworks, A New Trend on the Continent. (*Steel Rev.*, 1957, Jan., 49–55). Mainly statistical.

Investment in Steel. 1. 2. (*Steel Rev.*, 1957, Jan., 22–25; 26–34). Estimates of needs, of additional earnings needed for expansion and possible sources, and the effects of depreciation and taxation are indicated.

The Exports from the Jesenice Ironworks, Past and Present. K. Rosenstein. (*Nova Proizv.*, 1954, **5**, (3–4), 285–293). The development of the export trade is outlined, culminating in the ferromanganese production of 1870–1890. Export was resumed in 1952 and nails and welding rods were sent to Turkey, Egypt and Pakistan. Exports of 5000 t were expected in 1954.

Reflections on the Metallurgy of Iron and Steel. J. A. Riviere Manen. (*Inst. Hierro Acero*, 1957, **10**, Apr.-June, 171–186). [In Spanish]. A brief history of the iron and steel industry is given, and the rapidly increasing world production since 1945 is emphasized. The steel industry of the U.S.A. is taken as an example, and the basis of the high productivity there is explained in terms of technical, economic, and social factors. From this, several general conclusions are drawn, particularly that small scale plants could adopt a similar organization. It is also necessary to take into account the economic, technical, and human factors in order to obtain high productivity.—P. S.

The Factor-Analysis Method of Cost Accounting Exemplified by the Operation of an Open-Hearth Furnace. J. Hoffstadt. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1488–1496). A mathematical-statistical method is developed and discussed.

MISCELLANEOUS

Production of Manganous Sulphate Solution Fit for Electrolysis from Urkut Washery Slimes. Z. Horváth. (*Acta Tech.*, 1957, **18**, 3/4, 209–229). [In English].

Molybdenum, its Extraction and Metallurgy. M. Warriner. (*Mét. Constr. Mécan.*, 1957, **89**, June, 539–546). A description is given of the operation, concentration, and processing of Mo ore at the Climax Mine, Colorado, U.S.A. A short review is also made of the consumption and use of Mo and its alloys in the chemical industry.—B. G. B.

On the Crystallization of Mixtures in the System FeS–Co_9S_8. N. G. Moleva, P. S. Kusakin, E. A. Vetrenko, and N. P. Duev. (*Zhur. Priklad. Khim.*, 1957, **30**, Sept., 1402–1405).

Thermal and Magnetic Properties of Iron Sulphides with Nickel Arsenide Structure. S. Maeda. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9A**, Oct., 347–373).

Preparation of High-Purity Electrolytic Chromium. P. M. Gruzensky and F. E. Block. (*U.S. Bur. Mines Rept. Invest.*, 1957, No. 5305, Jan., pp. 11).

Process and Quality Control for Management. W. T. Hayter. (*Blast Furn. Steel Plant*, 1957, **45**, June, 601–607; July, 731–736). Details are given of the methods used by the Youngstown Sheet and Tube Co., U.S.A., for checking quality control.—B. G. B.

Training of Labour in the Jesenice Ironworks. U. Polde. (*Nova Proizv.*, 1954, **5**, (3–4), 293–297). **The Organization of Safety Precautions. [At Jesenice].** Z. Franc. (298–303).

Accident Statistics of the German Iron and Steel Industry During 1956. H. Antoni. (*Stahl u. Eisen*, 1957, **77**, Nov. 14, 1692–1698). A statistical analysis. The number of accidents in the works was lower than in previous years, but the number of accidents on the way to and from the works has increased substantially.

Injury Experience in the Metal and Nonmetal Industries 1954. J. C. Machisak, N. W. Kearney, and E. Dixon. (*U.S. Bur. Mines Inf. Circ.*, 1957, No. 7798, Aug., pp. 56). An account, mainly statistical, of injuries in mining and related operations.

The Increase of Labour Productivity in the Iron and Steel Industry. M. N. Timolshpol'sky. (*Stal'*, 1957, (11), 1011–1013).

The Growth of Ferrous Sulphide on Iron. R. A. Meussner and C. E. Birchenall. (*Corrosion*, 1957, **13**, Oct., 677–689). Measurements were made in S vapour at 650–900° C at 10–500 mm pressure. The iron was found more mobile than the sulphide and self-diffusion coefficients were calculated. Inert markers were often found far from the position expected, which has been attributed to cracking. Non-reactive inclusions are found to slow down the rate of sulphidation.

On a Method of Electrolytic Concentration of Iron in Solution. P. Deschamps. (*Chim. Anal.*, 1957, **39**, Sept., 329–330). A method is given for concentrating insoluble ferric hydroxide inside a cellulose acetate diaphragm round the cathode.

Electrowinning Chromium Metal. J. B. Rosenbaum, R. R. Lloyd and C. C. Merrill. (*U.S. Bur. Mines Rept. Invest.*, 1957, No. 5322, March, pp. 58). Laboratory studies of production from ore or ferrochrome are described.

BOOK NOTICES

HOT DIP GALVANIZERS ASSOCIATION. "*General Galvanizing. A Manual of Good Practice.*" La. 8vo, pp. 56. Illustrated. London, 1957: The Association. (Price 25*s.*).

This book is a combined effort by the Technical Committee of the Hot Dip Galvanizers Association and the British Non-Ferrous Metals Research Association. The result is an essentially practical treatment of Hot Dip Galvanizing in which the scientific details, which have been kept to a minimum, can be relied upon.

There are twelve short technical sections and a useful index. The first section is an Introduction, dealing mainly with the nature of a galvanized coating and the types of basis material to be coated—steel, cast iron, and wrought iron.

This is followed by four sections which deal with the preparation of the work, degreasing, pickling, grit blasting, and, in some cases, prefluxing.

The next four sections deal with the dipping operation itself and the three related subjects, Fluxes, Ash Formation and Dross Formation.

The next section is described as "Transport and Storage" but actually consists, almost entirely, of a discussion of White Rust and its prevention by chromating and other methods. This material could have been included with the next and final

section on "Finishing Treatments"—chiefly phosphating and painting.

Although there are no real errors in this excellent little book there are a few misleading statements. The distinction between Wet and Dry Galvanizing on page 7 may be questioned. It implies that Wet Galvanizing is so called because the zinc *wets* the steel, and that in the Dry Process there is no flux blanket so that the bath is *dry*. The terms wet and dry surely refer to the condition of the article when dipped. The classified instructions, on page 39, for the control of Dross formation give the impression that thorough washing to remove pickle salts is important only in Dry Galvanizing—this recommendation being omitted in the other sections. In fact rinsing is more important in Wet Galvanizing, as indeed is stated on page 37 under "pickle salts."

The book is well printed and strongly bound, as such a Manual should be. Its price, 25*s*., seems high even by present standards, for a slim volume of only 56 pages.—M. L. Hughes.

Larke, Eustace C. "*The Rolling of Strip, Sheet and Plate.*" With a Foreword by Maurice Cook. 8vo, pp. xi + 404. Illustrated. London, 1957: Chapman & Hall, Ltd. (Price 63*s*.).

This book deals with almost all aspects of the rolling of both steel and non-ferrous metals into flat products. It gives the soundest theories, and shows how to apply these to practical problems in the industry. Where no accurate solutions to problems exist, the author gives the best approximate solutions, thus reducing trial and error under mill conditions, which can be an expensive method of achieving a certain result.

Chapter one deals with advances leading up to the present modern continuous hot and cold sheet and strip mills, and Chapter two with special types of mill and the reasons for their design; cluster mills, Sendzimir mills and planetary hot rolling mills are described. Chapter three describes the calculations for the design of rolls and automatic means of grinding the cambers required. Chapter four discusses the effects of variations in entry thickness, hardness, temperature, roll eccentricity, tension and acceleration on rolling practice; three methods of automatic gauge control are described.

Chapter five surveys the effects on rolling load of factors such as roll-surface condition, rolling speed, strain rate, properties of the strip, roll diameter, friction, slip and tension. Chapters six and eleven are concerned with methods for calculating cold rolling load, torque and horse power; it is to be regretted that the equations of Bland and Ford are not given. Methods of measuring rolling load are described. Chapter seven deals with the effects of interstand tension, and Chapters eight and nine with frictional conditions and the resistance to deformation of different metals; the effect of strain rate on resistance deformation is considered in some detail. Chapters ten and twelve give formulæ for, and examples of, hot-rolling load, torque and horse-power calculations. Chapter thirteen deals with productivity, and shows that output is dependent more upon factors such as handling time and coil size than upon mill speed.

The book is illustrated throughout in a very pleasing way with graphs and tables of data for all related variables.

The reviewer is convinced that the book will be widely studied, and wishes to draw attention to the following points so that future editions may be amended.

On p. 75, Fig. 3.4 gives the factor h/T for the ordinate, whereas this should be h/r.

On p. 305 the explanation of the minus sign in equation 92 is stated to relate to the roll pressure from entry to exit. This may lead to a misunderstanding, and perhaps it would be better if it were stated as "the roll pressure from the plane of entry *towards* the plane of exit" or, better still, "the roll pressure from the plane of entry to the neutral point."

L. G. M. Sparling.

Lothers, John E. "*Design in Structurla Steel.*" Second edition. 8vo, pp. x + 454. Illustrated. London, New York, Toronto, 1957: Longmans, Green & Co. (Price 56*s*.).

As emphasized by the author, this volume is intended to appeal to a wide range of individuals including the student, the engineer in practice and the instructor, and it comprises chapters on beams and girders, tension and congression members, connections, baseplates, composite beams and girders, roof trusses, frames for industrial buildings and steel bridges. The practice described and specifications complied with are, of course, all American. Loads and stresses quoted are in accordance with the current specifications of American authorities, e.g. American Institute of Steel Construction, American Railway Engineering Association, etc. Examples are given for the student to solve; specific steps in the procedure for design are detailed; and bibliographies are given at the end of each chapter. A useful feature is the discussion in sequence of riveting, bolting and welding as alternative means of forming connections.

The arrangement of the text, therefore, covers the usual major components and classes of structure in steel construction and to that extent will be of use to the engineer associated with iron and steelworks. The treatment of industrial buildings and bridges is limited, however, to a chapter each, so that the range of possibilities in each group could not be exhaustively considered; as an introduction, however, both are useful. Multi-storey buildings are not dealt with in any one section.

As regards types of construction considered, all are conventional except perhaps the description of the tee-flanged, multiple-web type of built-up girder. The need of the Industry today is to explore and utilize new and improved methods of design and construction, but, with the exception of high-strength bolts, no noticeable space has been devoted to new techniques such as continuous frames and collapse design, nor have fatigue effects been especially considered.

The merits of relative forms of construction are outside the scope of this work, so that from the point of view of its use to the engineer in iron and steelworks this volume may ensure sound conventional design, but it cannot be said that it will inspire new and original ideas.—J. S. Terrington.

Schrader, Angelica. "*Ätzheft.*" Verfahren zur Schliffherstellung und Gefügeentwicklung für die Metallographie. Neu bearbeitet im Max-Planck-Institut für Eisenforschung, Düsseldorf, unter Mitwirkung von Dr. Werner Schaarwächter. Vierte Auflage. 8vo, pp. [iv+] 50. Illustrated. Berlin-Nikolassee, 1957: Gebrüder Borntraeger. (Price DM. 7.80).

This is the 4th edition of an etching handbook which should prove very useful to anyone interested in practical metallography and who can understand German.

There are some general notes on polishing, mounting, electrolytic polishing and etching, and a short bibliography. Most of the information, however, is classified according to the principal metal present in the alloy undergoing examination; thus there are sections on aluminium, copper, iron, magnesium, nickel, titanium, zinc, etc. The function of each etching reagent is given, followed by its composition and method of use, so that the reader can quickly select the procedure most suited to his particular purpose.

Out of a total of 50 pages, 12 deal specifically with ferrous materials giving 32 different techniques for developing microstructure, identifying alloy carbides, distinguishing sigma phase, etc. There are, however, a few minor omissions, e.g. although a method of lead printing is described, the very useful reagent for etching leaded steel (2% Nital saturated with potassium iodide) is not given, nor is Marble's reagent for stainless steel included. It would also have been useful to be told which reagents are suitable for martensitic stainless steels and which for austenitic steels.—P. Judd.

NEW PUBLICATIONS

British Standards Institution. B.S. 2920: 1957. "*Cold-Reduced Tinplate and Cold-Reduced Blackplate.*" 8vo, pp. 17. Illustrated. London, 1957: The Institution. (Price 4*s*. 6*d*.).

Calvo Rodés, Rafael. "*Metales y Aleaciones.*" Su Constitucion, Estructura, Propiedades y Tratamientos." Tomo II. "Propriedades y Tratamientos." La. 8vo, pp. xvii + 720. Illustrated. Madrid, 1957: Instituto Nacional de Tecnica Aeronautica "Esteban Terradas."

Considine, Douglas M. (Editor-in-Chief). "*Process Instruments and Controls Handbook.*" Prepared by a Staff of Specialists. 8vo, pp. xxiii + 1382 (paginated by sections). Illustrated. New York, Toronto, London, 1957: McGraw-Hill Book Co., Inc. (Price 147*s*. 6*d*.).

Engel, Ludolf. "*Die Maschinen der Eisenhüttenwerke.*" (Sammlung Göschen. Bd. 583/583a). Pp. 156. Illustrated. 1957, Berlin: de Gruyter. (Price, DM. 4.80).

Hall, John Howe. "*Steel Foundry Practice.*" First edition. 8vo, pp. viii + 496. Illustrated. Cleveland, Ohio, 1955: Penton Publishing Company. (Price 96*s*. 6*d*.).

Halla, Franz. "*Kristallchemie und Kristallphysik metallischer Werkstoffe.*" (3. umgearb. Aufl.). 8vo, pp. xvi + 737. Illustrated. Leipzig, 1957: Barth. (Price DM. 50.00).

Konopicky, Kamillo. "*Feuerfeste Baustoffe-Herstellung und Verwendung.*" 4to, pp. xiv + 553. Illustrated. Düsseldorf, 1957: Verlag Stahleisen m.b.H. (Price DM. 57.50).

Leck, J. H. "*Pressure Measurement in Vacuum Systems.*" 8vo, pp. 144. Illustrated. London, 1957: Chapman & Hall, Ltd. (for the Institute of Physics). (Price 30*s*.).

"*Quin's Metal Handbook.* 1956–57." 8vo, pp. 704. London, 1957: Metal Information Bureau Ltd. (Price 25*s*.).

Sjöstrand, F. S., and J. Rhodin. "*Electron Microscopy. Proceedings of the Stockholm Conference Sept.* 1956." 8vo, pp. xi + 355. Illustrated. Stockholm, 1957: Almqvist and Wiksell. (Price DM. 67.50).

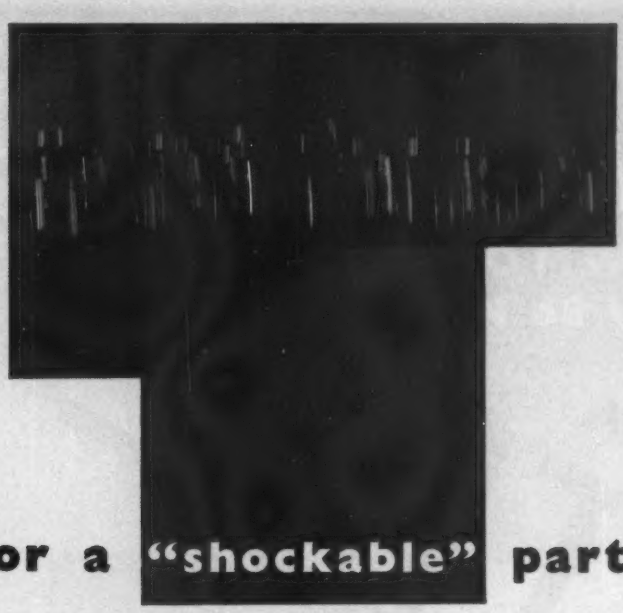
Stapf, Helmut. "*Grundlagenchemie für technische Berufe.*" (11 verb. u. erw. Aufl.) 8vo, pp. xi + 289. Illustrated. Leipzig, 1957: Fachbuchverlag. (Price DM. 7.80).

United States Steel Corporation. "*The Making, Shaping and Treating of Steel.*" Seventh edition. La. 8vo, pp. xxiii + 1048. Illustrated. Pittsburgh, Pa., 1957: The Corporation. (Price 77*s*. 6*d*.).

Verein Deutscher Eisenhüttenleute. "*Anhaltszahlen für die Wärmewirtschaft in Eisenhüttenwerken.*" Herausgegeben von der Energie- und Betriebswirtschaftstelle des Vereines Deutscher Eisenhüttenleute (Wärmestelle, Düsseldorf). 5., völlig neubearbeitete Auflage. La. 8vo, pp. xii + 472. Illustrated. Düsseldorf, 1957: Verlag Stahleisen m.b.H. (Price DM. 62.–).

Verein Deutscher Ingenieure and Verein Deutscher Giessereifachleute. "*Konstruieren und Giessen.*" 4to, pp. 155. Düsseldorf, 1957: Giesserei-Verlag; VDI-Verlag. (Price DM. 18.50).

Wirtschaftsvereinigung Eisen- und Stahlindustrie. "*Statistisches Jahrbuch für die Eisen- und Stahlindustrie,* 1956/57." Pp. x + 263. Illustrated. Düsseldorf, 1957: Verlag Stahleisen. (Price DM. 10.00).



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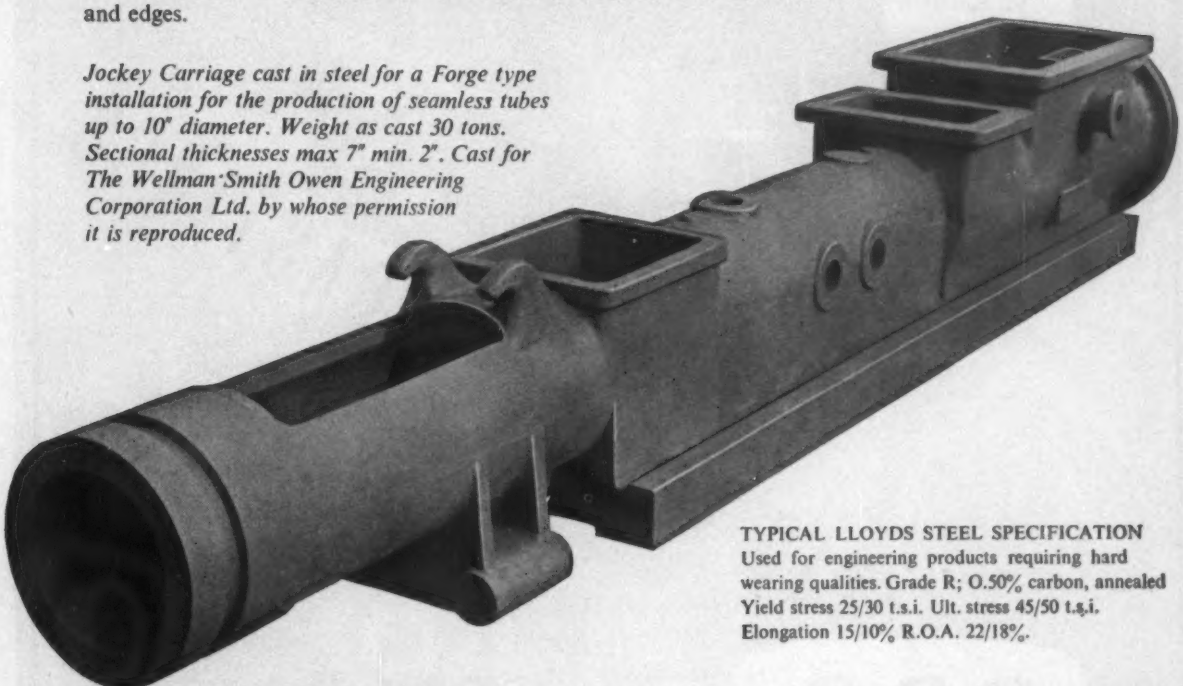

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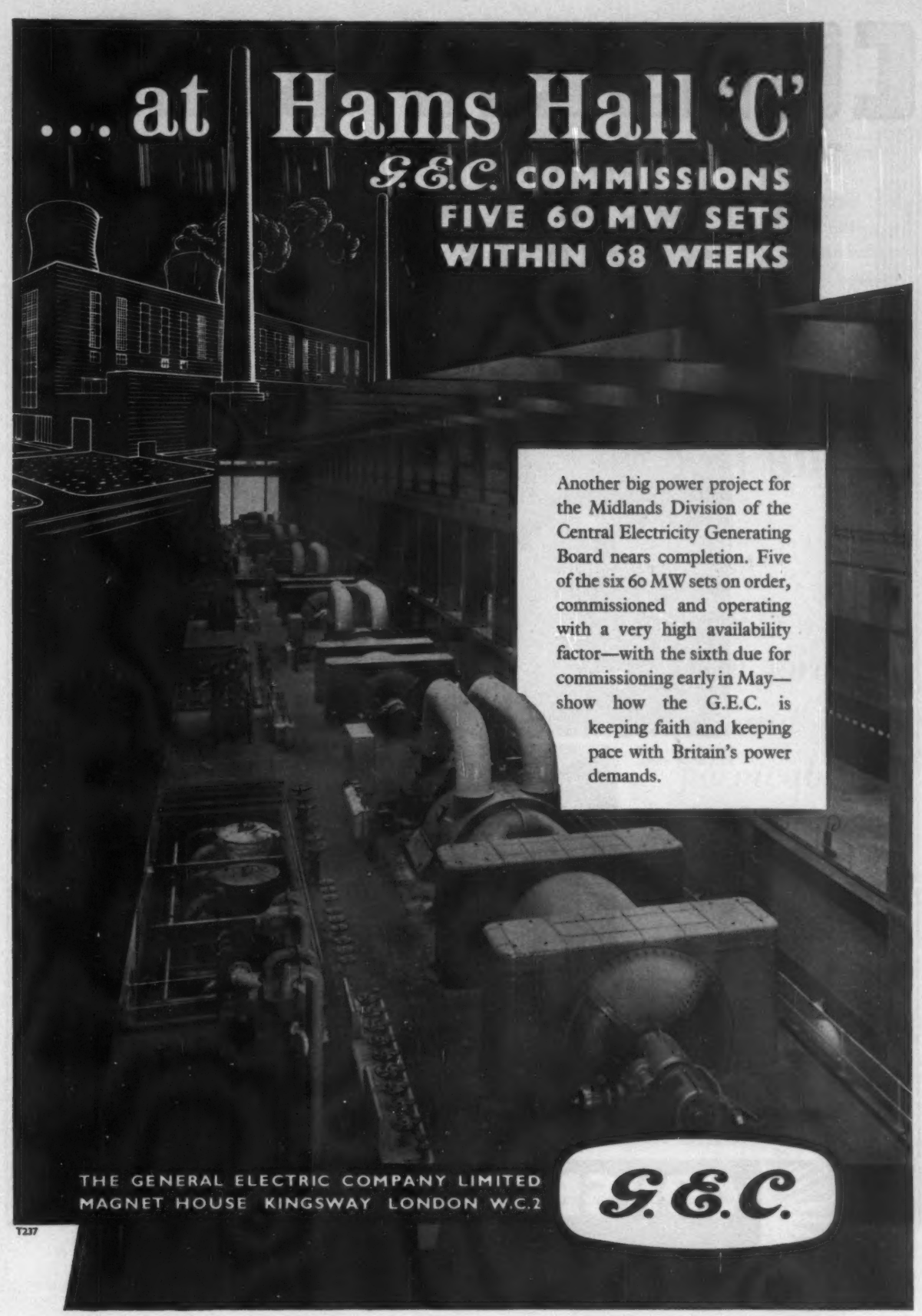
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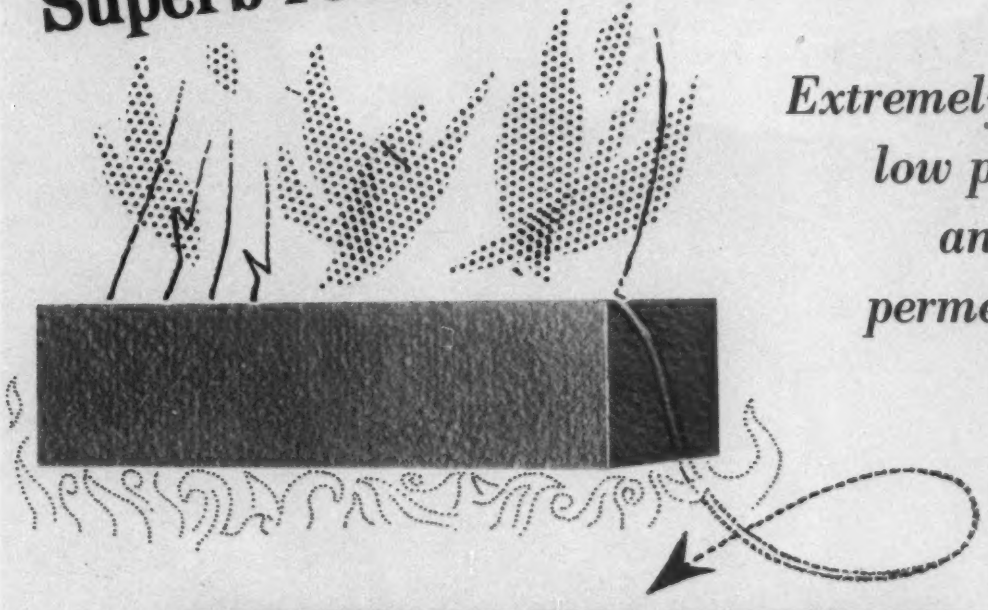

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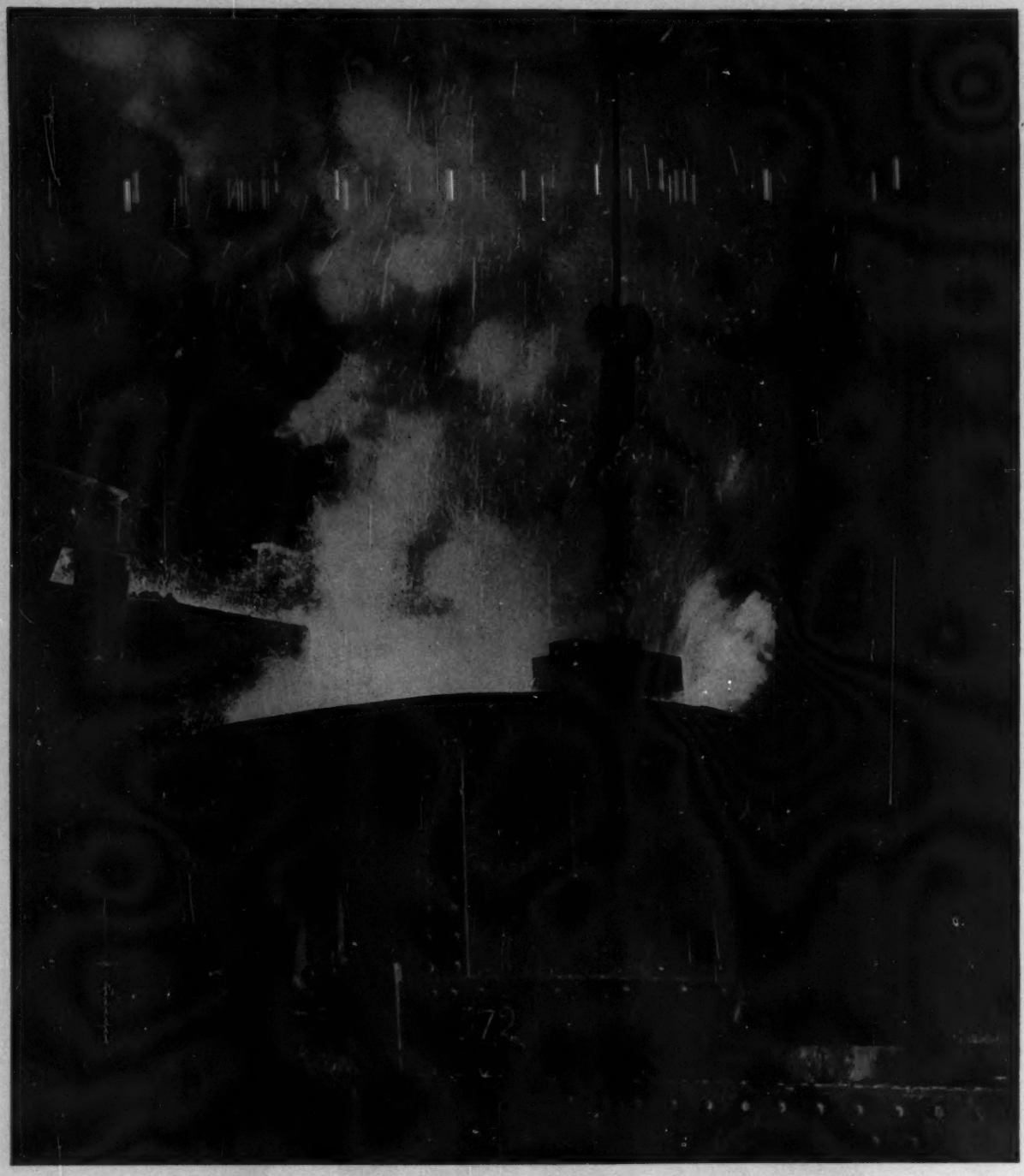

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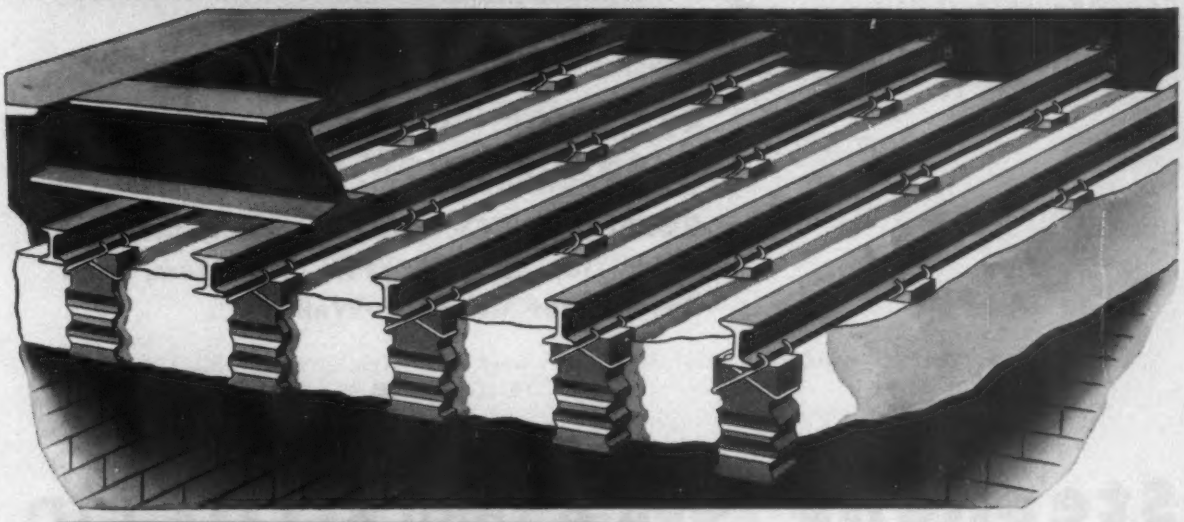

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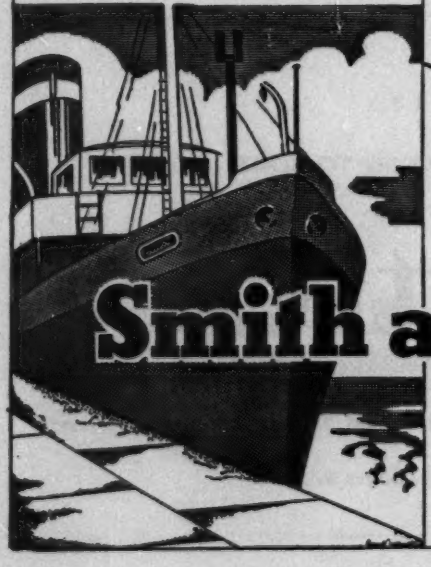

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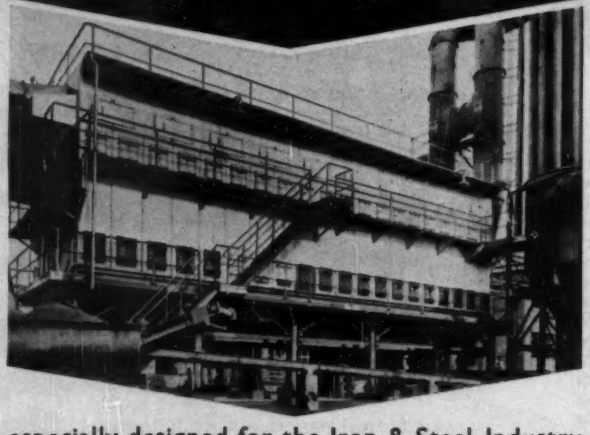

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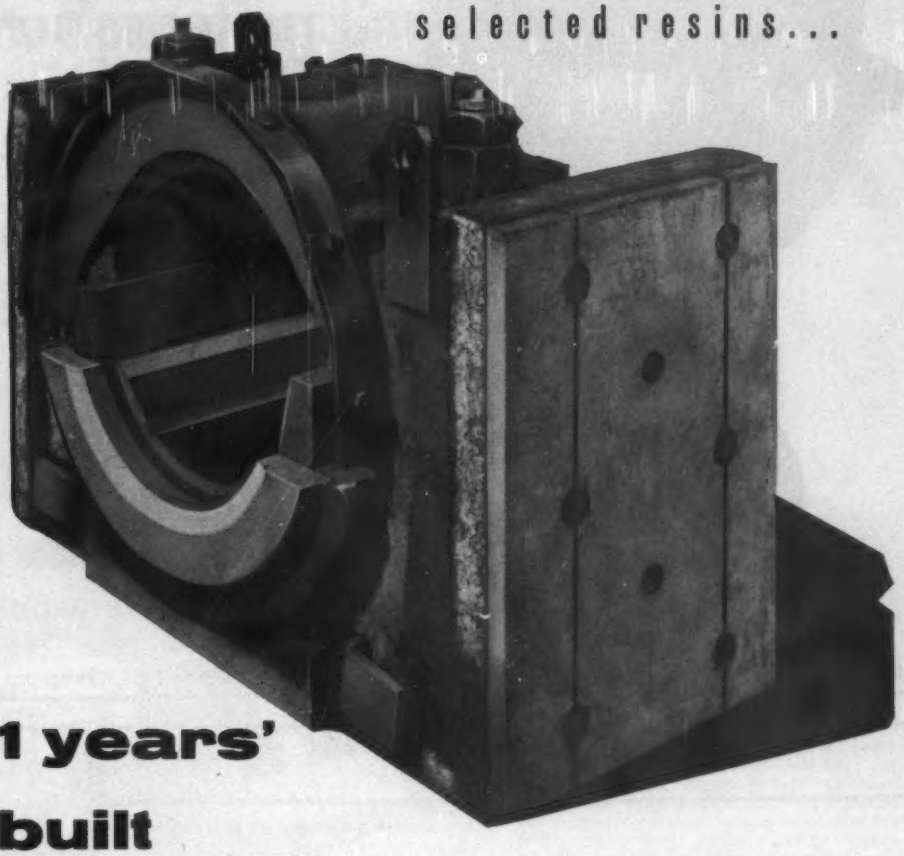

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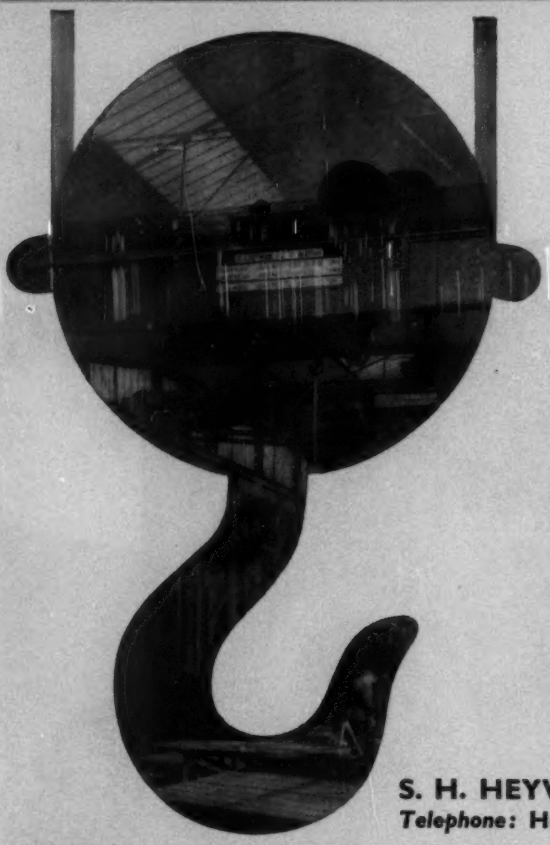

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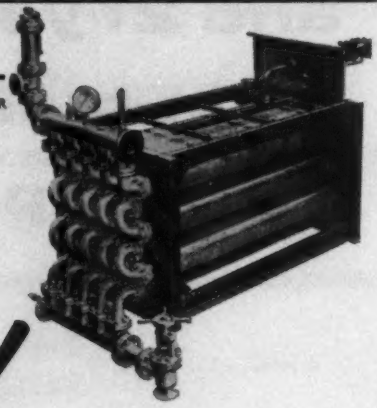

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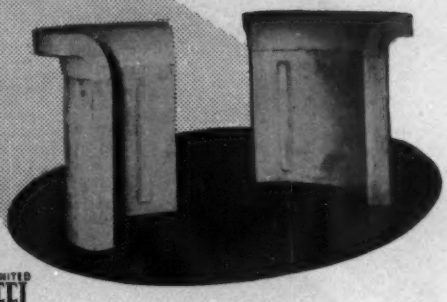

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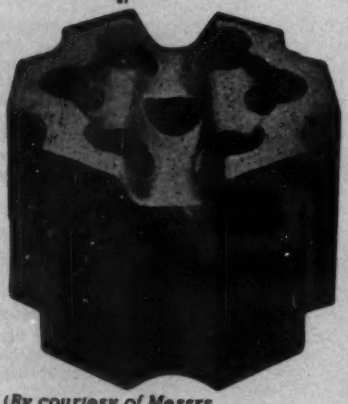

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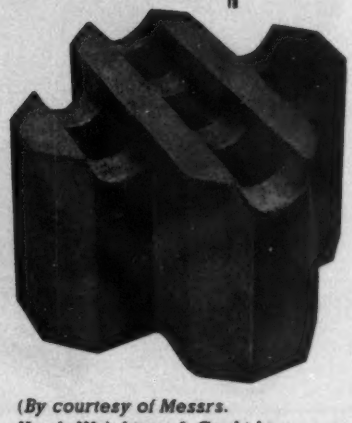

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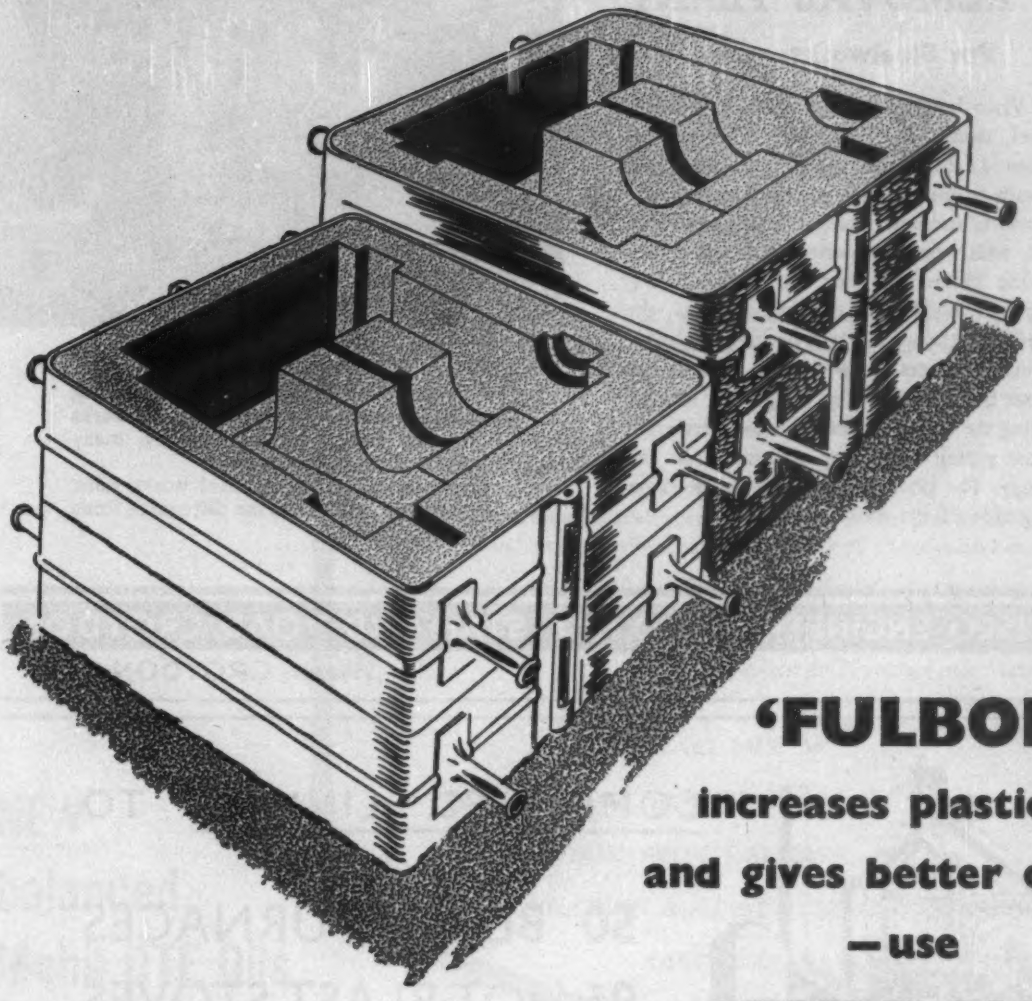

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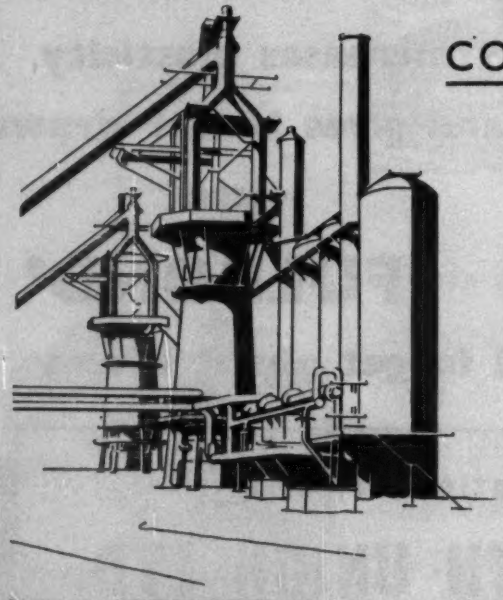

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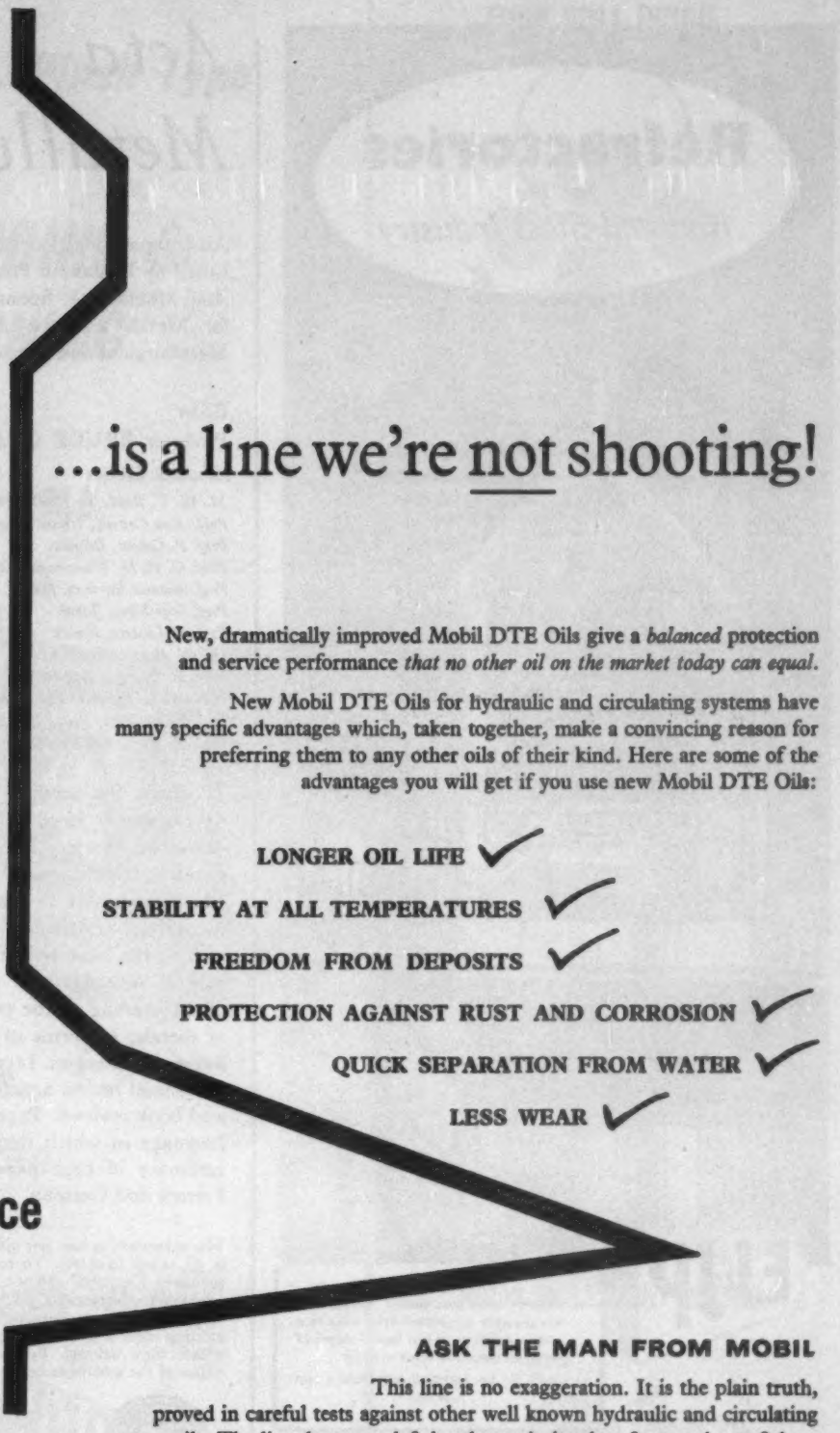

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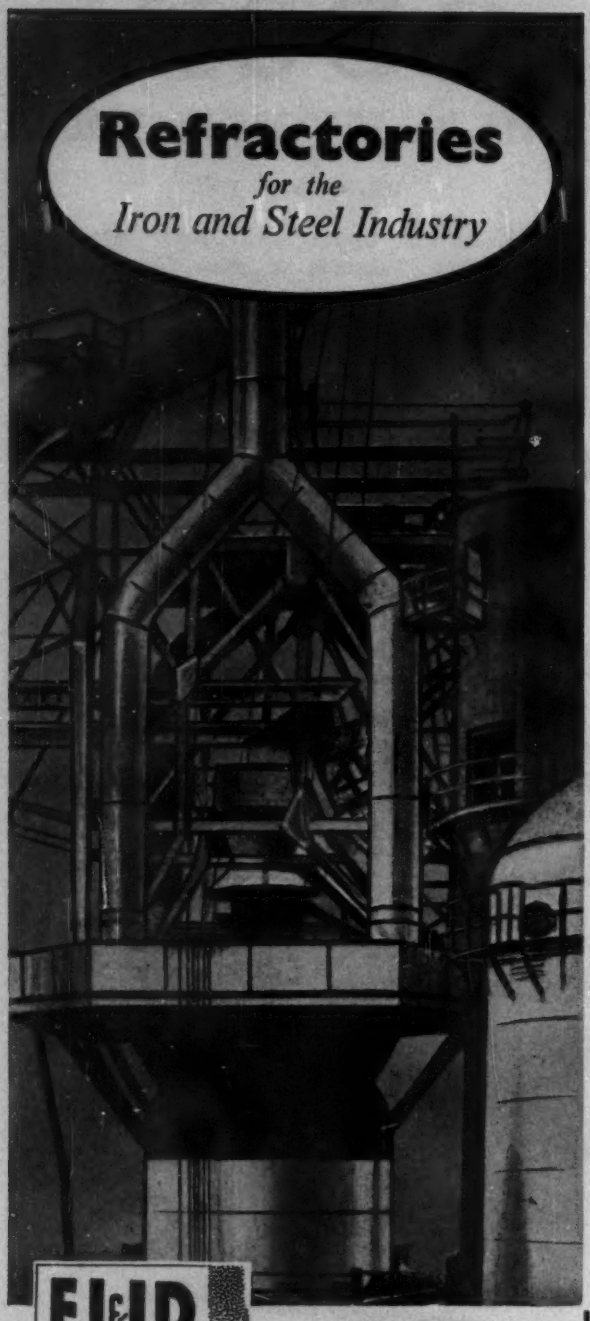

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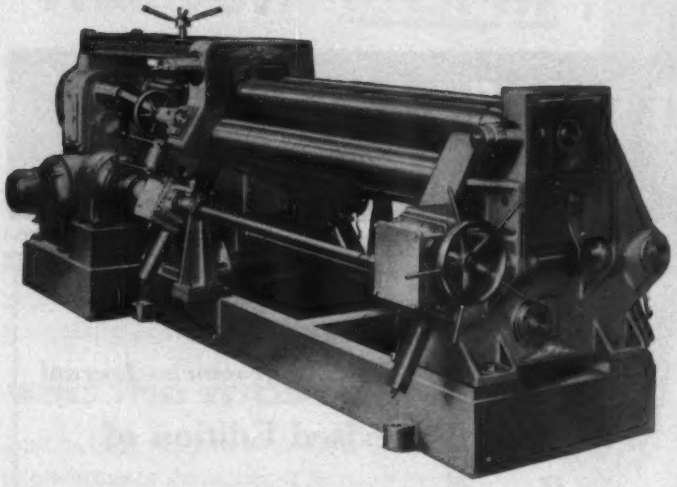

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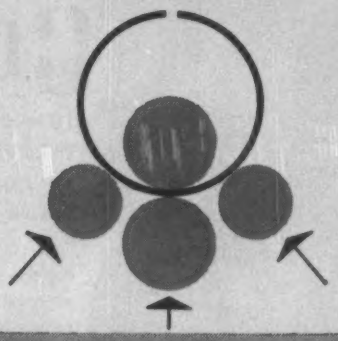

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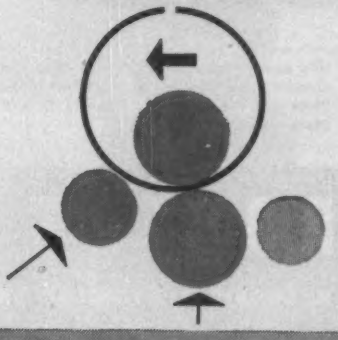

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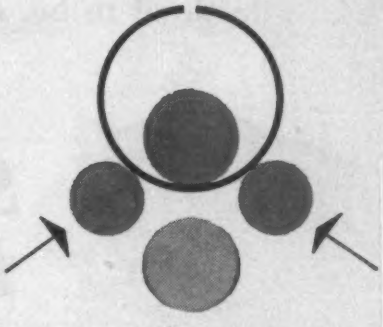

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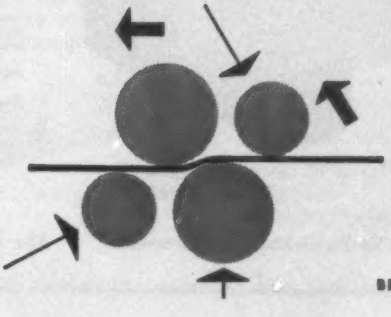

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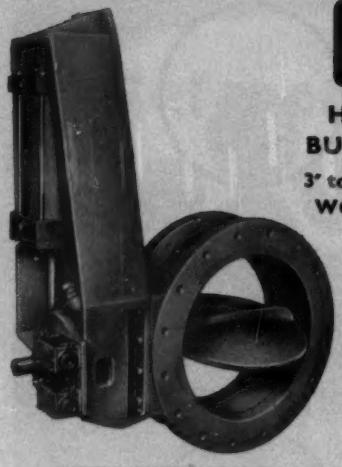

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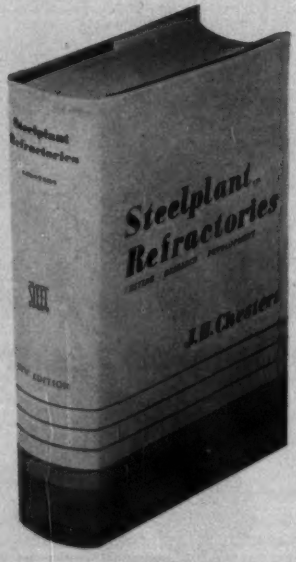

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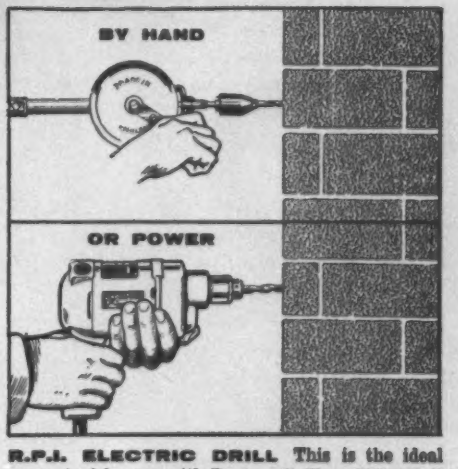

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Published at the offices of The Iron and Steel Institute, 4, Grosvenor Gardens, London, S.W.1, and Printed in Great Britain by HARRISON & SONS, LTD., by Appointment to Her Majesty The Queen, Printers, London, Hayes (Middx.) and High Wycombe.

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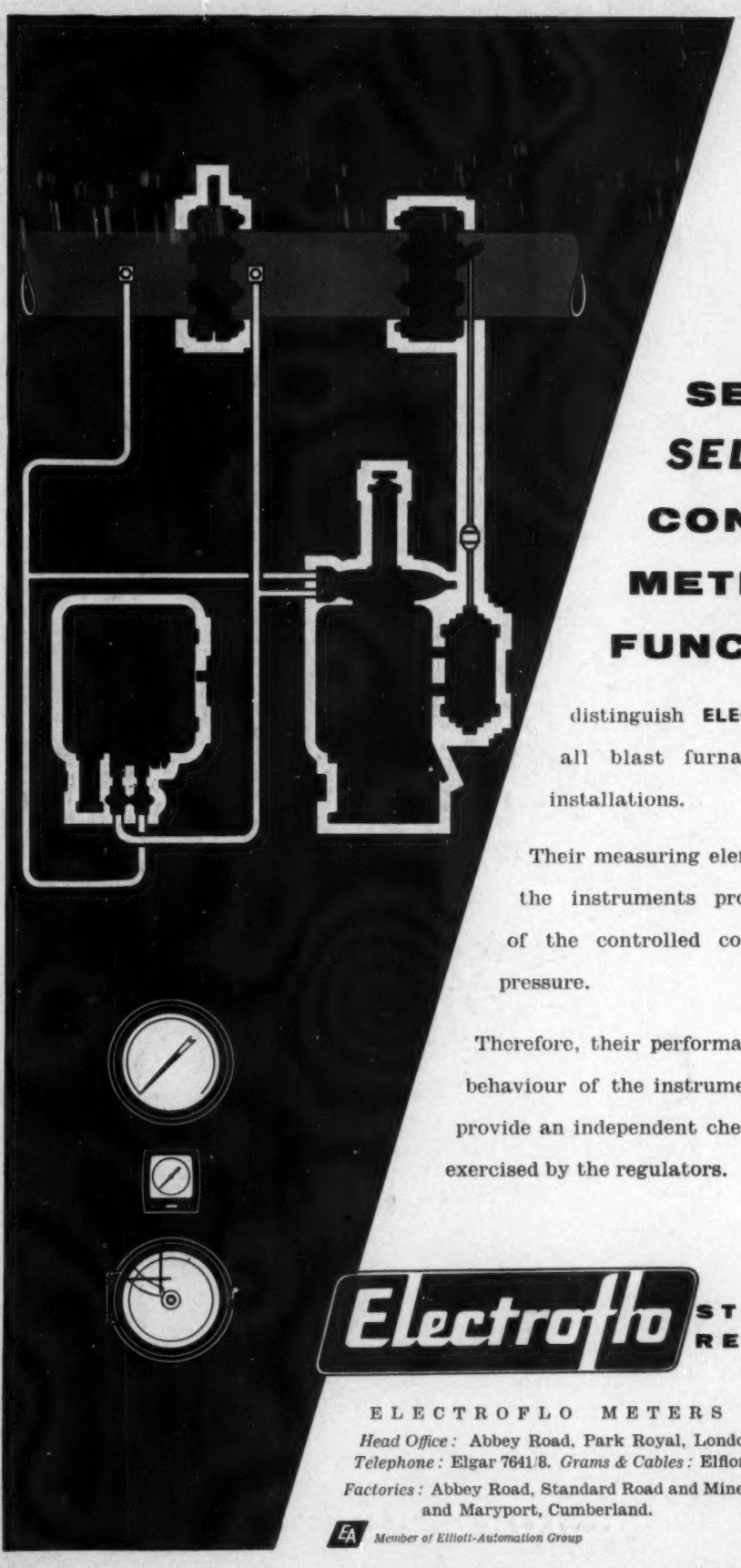

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